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EVALUATION OF FULL-FAT CANOLA SEED AS A SOURCE OF ENERGY AND PROTEIN FOR GROWING AND LAYING CHICKENS

by

ROBERT ARTHUR FOREMAN

(C)

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

IN

POULTRY NUTRITION

DEPARTMENT OF ANIMAL SCIENCE

EDMONTON, ALBERTA

SPRING, 1987

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"The moving finger writes and having writ
Moves on: Nor all your Piety nor your wit
Shall lure it back to cancel half a line
Nor all your tears wash out a word of it."

Edward Fitzgerald (1809-1883): The Rubáiyát of Omar Khayyám of Naishápúr, verse 71.

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled EVALUATION OF FULL-FAT CANOLA SEED AS A SOURCE OF ENERGY AND PROTEIN FOR GROWING AND LAYING CHICKENS submitted by ROBERT ARTHUR FOREMAN in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE in POULTRY NUTRITION.

Frank Aherne

Supervisor

Date Dec 5 1986

Dedication

To my parents

Whose unfailing encouragement

Has seen me through my educational career.

Abstract

Experiments were conducted at the University of Alberta Poultry Research Unit to evaluate the nutritive value of full-fat Tobin canola seed (CS) in the diets of laying hens and to determine the effect of Jet-Sploding™ on the nutritive value of CS for chickens.

Egg production expressed in terms of percent hen-day or percent hen-housed production and average numbers of eggs produced on a hen-housed or hen-day basis was not ($P>0.05$) affected by dietary treatment. Feed intakes and feed efficiency were significantly ($P<0.05$) lower on both corn and CS supplemented diets. Of the cereal grains used, birds fed the corn-based diets tended to produce the largest eggs. Net income ($/bird), was highest from birds fed the barley diets ($P<0.05$). Income was not ($P>0.05$) affected by the addition of CS to the diet. Based on the results obtained in this study, it would appear that CS can be used at a level of 10% as a satisfactory high energy supplement in barley or wheat-based rations for laying hens.

True metabolizable energy (TMEn) estimates for raw and jet-sploded full-fat CS samples (± SE) were 5.14±0.08 and 5.15±0.08 kcal/gDM, respectively. Jet-sploding resulted in slightly higher ether extract values in the samples and complete elimination of myrosinase activity. There was however, no ($P>0.05$) improvement in the TMEn values of jet-sploded CS as compared to those from the raw seed. In a trial with broiler chickens weight gains to 3 wks of age were not increased by jet-sploding, although feed:gain values were ($P<0.05$) improved, and were equivalent to that obtained from the corn-soybean meal controls. Based on these results, it is suggested that a temperature of 116°C in the Jet-Sploder (for 22.2 sec) resulted in effective elimination of myrosinase and maximal oil liberation.

Apparent metabolizable energy (AMEn) estimates of jet-sploded full-fat CS were consistently greater than estimates of raw CS for both adults and chicks when measured by either the total collection or the dysprosium (Dy) ratio techniques, (5.06 vs 4.26 kcal/gDM) and (4.39 vs 3.80 kcal/gDM), and (4.95 vs 3.47 kcal/gDM) and (4.51 vs 3.36 kcal/gDM), respectively. Lipid digestibilites in both adults and chicks were ($P<0.001$) improved by jet-sploding with adults demonstrating higher ($P<0.001$) apparent lipid digestibilites. This

may in part explain the lower AMEn results obtained from chicks compared to those derived from adult birds. Mean Dy recovery in chicks following a 16 hr post-collection fast was 94.3±1.4%. Mean Dy recovery in adults following a 24 hr post-collection fast was 86.5±3.6%. These relatively high recoveries indicate that Dy is a very good inert marker for digestibility studies in chickens and lends credence to the AMEn estimates derived using this technique.

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I. Introduction

Canola rapeseed is often referred to as Canada's Cinderella crop. The phenomenal success of this relatively new crop has been due to the exceptional cooperation between the research community and agribusiness. Rape is a member of the *Cruciferae* family. Two species of summer rape are commonly grown in Canada: *Brassica campestris* L. commonly called Polish or turnip rape and *B. napus* L. commonly called Argentine rape. *B. campestris* has a maturity requirement similar to the mid-range of barley cultivars and is thus best suited to the parkland belt of the prairies. *B. napus* has a maturity requirement similar to the bread wheats and is thus suited to the southern prairie areas. Although *B. napus* was initially the major species grown, the shorter growing period, greater drought and shattering resistance of the pods during harvesting of *B. campestris* have made it the cultivar of choice in the northern areas where the bulk of the rapeseed (RS) production is presently concentrated.

RS refers to cultivars producing traditional quality seed. Canola™ is a trademark held by the Canola Council of Canada and can be used to describe seed, seed products and cultivars producing seed with less than 3mg/g of normally measured glucosinolates and 5% or less erucic acid, a 22 carbon, long chain fatty acid that does not occur in other edible oils such as soybean, sunflower, peanut and palm oils. The reduction of erucic acid (C22:1) in canola seed (CS) oil has resulted in a marked increase in oleic acid (C18:1) together with smaller increases in linoleic (C18:2) and linolenic (C18:3) acids. The relatively high linolenic acid content does, however, pose problems with the stability of extracted canola oil. Since the discovery of the low glucosinolate cultivar Bronowski in 1967, there are available commercially in Canada at least 6 double zero (low glucosinolate, low erucic acid) CS cultivars: Altex, Andor, Candle, Regent, Tobin and Westar (Kondra 1985).

The commercial production of CS in Alberta has increased rapidly in the last decade from 0.68 million hectares in 1975 to 1.17 million hectares in 1984, producing 1.29 million tonnes in that year (Statistics Canada 1984). The availability of such large quantities of canola has resulted in a rapidly expanding oil seed processing industry. The crushing of CS produces two valuable products; 40% oil and a meal which contains 35-38% crude protein.

Canola oil currently constitutes 55% of the edible non-animal based oil presently consumed in Canada (Vemann 1985). The meal, a by-product of the oil extraction process, is used as a high protein supplement in diets for livestock and poultry.

Limitations to the use of CS in poultry diets has been due to the presence of goitrogenic substances derived from the enzymatic hydrolysis of glucosinolates. This coupled with the low digestible energy, high fiber and tannin levels, reduced feed intakes due to unpalatablity of canola supplemented diets and lower amino acid availabilities have limited the inclusion of canola meal and seed in poultry diets.

A. FACTORS WHICH AFFECT THE NUTRITIVE VALUE OF CANOLA SEED

Glucosinolates

Glucosinolates are present in all cruciferous seeds and plants (Kjaer 1960). The structure of a generalized glucosinolate, which was established for sinigrin (Ettlinger and Lundeem 1956) is shown in Figure I.1. Glucosinolates differ only in the nature of the side chain '-R' in the formula. They are usually coupled with the potassium (K^+) cation except in sinalbin which is a salt of sinapine. The six major glucosinolates found in *Brassica napus* and *B. campestris* are illustrated in Table I.1.

Catabolism of Glucosinolates

The presence of glucosinolates in CS has been described as the single most important factor limiting its potential as a high energy protein supplement in the diets of non-ruminant animals. Glucosinolates co-exist with an enzyme called myrosinase and, although biologically inactive themselves, when conditions are present which bring about their hydrolysis, they yield a variety of goitrogenic and toxic compounds. Seven glucosinolate components are of significance in CS and canola meal (CM) (Bell 1984). It is these glucosinolate breakdown products which are largely responsible for the deleterious effects associated with feeding canola products to livestock (Fenwick and Curtis 1980).

Myrosinase

Myrosinases are a group of enzymes which occur in all cruciferous plants and have the systematic name thioglucoside glucohydrolase (EC 3.2.3.1.), (Gijzen and McGregor, unpublished). When the plant tissue is crushed in the presence of sufficient amounts of water (@ 13% moisture in the seed) (Youngs et al. 1981), myrosinase catalyses the hydrolysis of glucosinolates to glucose, sulphate and an unstable aglucone (Figure I.2). The further fate of this aglucone depends, in each case, on the character of the side chain '-R' and on the conditions prevailing during the enzymatic process. Various pathways to stable end-products are known and are frequently simultaneously involved. These include intramolecular non-enzymatic rearrangement to isothiocyanates, fragmentation to nitriles, rearrangement to thiocyanates or further hydrolysis to free thiocyanate ions (Bell 1984; Gijzen and McGregor, unpublished).

Even when the indigenous myrosinase has been properly deactivated (by heat treatment), it is still possible for the glucosinolates in the seed to be hydrolysed after consumption by the animal. Greer (1962) showed that glucosinolate hydrolysis by thioglucosidase enzymes isolated from the rat intestinal microflora occured, albeit much more slowly and erratically than in the intact plant. Greer and Deeney (1959) demonstrated the existence of myrosinase in certain bacteria such as *Escherichia coli*. Oginsky et al. (1965) identified various bacteria, including *Paracolobacterium*, from the intestinal tract of mammals, which also possess thioglucosidase activity. More specifically, Miguchi et al. (1974) and Marangos and Hill (1974) have reported the hydrolysis *in vivo* of glucosinolates in the hen. However, there is no information in the literature as to the extent of the activity of thioglucosidase in the gut and it does not appear to significantly influence the feeding quality of properly processed CS.

Anti-nutritional factors related to Glucosinolates

Thiocyanate

Thiocyanate ion has been known to act as a goitrogenic compound which inhibits the uptake of iodine and suppresses its conversion to triiodotyronine (T_3) and thyroxine (T_4), (Franklin et al. 1944). The goitrogenic effect of thiocyanate ion can be prevented or inhibited by simply increasing the iodine supplementation in the diet (Van Etten 1969).

Nitriles

Nitriles represent another group of compounds produced by hydrolysis of glucosinolates. Aherne and Kennelly (1982) in a review suggested that nitriles are not goitrogenic per se. Van Etten et al. (1969) demonstrated that nitriles are in fact toxic to rats, causing lesions in the liver and kidneys. Srivastava et al. (1975) demonstrated that feeding autolysed CM, which contains high levels of nitriles, resulted in depressed growth rates of both rats and chickens.

Tannins

Tannins are polyflavoid compounds that tend to accumulate in the seeds of the rape plant (Leung et al. 1979). Durkee (1971) indicated that most of the condensed tannins in CS are found in the hulls and dehulling of the seed has been shown to improve protein and energy digestibilities of the meal for rats (Leslie et al. 1973a) and for pigs (Sarwar et al. 1981).

Both hydrolizable and condensed tannins have been shown to have adverse effects on the performance of poultry (Clandinin 1961; Vohra et al. 1966). Yapar and Clandinin (1972) and Seth and Clandinin (1973) have reported that tannins reduced the dietary metabolizable energy (ME) for broiler chickens. On the other hand however, Mitaru et al. (1983) have reported the tannin content of canola hulls to range from 0.11 to 0.19% and have suggested that they have no deleterious effects on the nutritive value of CM for broilers.

Sinapine

Although the content of choline in CS is nearly three times that found in soybeans, most of this occurs as sinapine, the ester of 4-hydroxy 3, 5-dimethoxy-cinnamic acid (Fenwick 1982). The presence of sinapine in RS and its association with the laying of eggs with a fishy odor by some birds within a flock of brown-egg layers when fed a diet containing 10% rapeseed meal (RSM) have been reviewed by Pearson et al. (1980) and by Fenwick and Curtis (1980). The trimethylamine (TMA) found in eggs tainted with a fishy odor was the result of two factors: the conversion of sinapine to TMA by enteric bacteria found in the ceacae of layers (Mueller et al. 1978) and the inability of the bird to oxidise the absorbed TMA to an odorless trimethylamine oxide (TMAO) (Pearson et al. 1979). The impairment of the bird's ability to metabolise TMA was due to an abnormally low activity of the enzyme TMA oxidase in the liver of the bird laying the fishy egg.

Clandinin and Heard (1968) reported that sinapine produced no growth depressing effects in chickens. However, sinapine in CS has been suggested to be responsible for some of the palatibility problems associated with its usage, (Clandinin and Heard 1968; Fenwick and Curtis 1980). In Canada where the main commercial layer is the Single Comb White Leghorn (SCWL)- a white egg layer - fishy egg taint has not been reported in the field.

Goitrin

Goitrin results from the enzymatic hydrolysis of progoitrin (2-hydroxy-3-butenyl glucosinolate). The reaction yields 2-hydroxy-3-butenylisothiocyanate which is unstable and quickly cyclizes to 5-vinyl-2-oxazolidinethione, otherwise called goitrin due to its strong goitrogenic effects (Kjaer 1960). Goitrogens produce thyroid hypertrophy by diminishing the supply of thyroid hormones available to the body, this being accomplished by either inhibiting the uptake of iodine by the thyroid gland or preventing the binding of mono-iodotyrosine or diiodtyrosine with iodine to form either triiodothyronine (T_3) or thyroxine (T_4), (Ochetim et al. 1980). This leads to a net

reduction in circulating T_3 and T_4, resulting in stimulation of the hypophysis to produce thyroid stimulating hormone, which ultimately produces an enlargement of the thyroid gland.

Fiber

One of the major drawbacks to the use of CS in poultry diets is its high fiber content. This high fiber content is largely due to the high proportion of hull in relation to the size of the seed. Hulls comprise about 16-19% of seed weight (Appleqvist and Ohlson 1972; Shires et al. 1981). RS hulls are high in crude fiber (44%) and in acid and neutral detergent fiber (67 and 80%, respectively, oil-free basis), (Bell and Shires 1982; Bell 1984). The composition of hulls also differs between brown and yellow-hulled varieties, the latter containing less fiber (Stringam et al. 1974; Bell and Shires 1982). Cellulose is the dominant carbohydrate in CS hulls, and most of the remaining carbohydrates are pentosans. In view of the nature of the carbohydrate in CS hulls and the amount of lignin present, (12-24%), it is probable that the digestiblility of hull carbohydrates by chickens would be low (Bell 1984).

B. FULL-FAT CANOLA RAPESEED IN POULTRY RATIONS

It has been shown that the feeding value of CM compares quite favourably with that of soybean meal (SBM), in contrast to the results obtained with older RSM samples (Rapeseed Association of Canada 1977; Canola Council of Canada 1980). Based on such studies, a general recommendation for the use of up to 10% CM has be made for laying hen and broiler diets. Earlier work with full-fat RS suggested that this product might have a potential as a high-energy feed ingredient in poultry diets (Woodly et al. 1972; Bayley and Summers 1975; Olomu et al. 1975b,c).

Intact RS is a high energy material due to the high level of oil (40%) in the seed. Together with a protein content of about 20-23%, it is a potentially valuable feed ingredient. Jones and Sibbald (1979) reported that whole RS (*B. napus* cv. Tower) contained 6.67 and 4.99 kcal of gross (GE) and true metabolizable energy (TME) per gram of dry matter,

respectively for chickens (27.9 and 20.9 MJ/kg). Sibbald and Price (1977) obtained TME values ranging from 3.91-5.35 kcal/gram DM for 9 varieties of *B. campestris* CS and 4.59-5.71 kcal/gram DM for 10 varieties of *B. napus* CS.

Woodly et al. (1972) showed that, provided the seed was heat-treated prior to feeding, ground RS was a satisfactory source of energy and protein for chicks. Further work, (Leslie and Summers 1972) established that ground, unprocessed full-fat *B. campestris* seed could be given to layers at low (5%) levels without reducing egg production and feed consumption. When 15% of the diet was heat-treated seed, some birds ceased laying altogether. Increasing the level of RS in the diet was also associated with the laying of smaller eggs, an observation which had previously been made for birds fed RSM and which at that time, had been attributed to dietary amino acid imbalance. Similar depression of egg production and egg size was also found when the same seed, after heat treatment, was incorporated at levels of 20% of the diet (Leslie et al. 1973b).

Growth depression has sometimes followed the use of full-fat RS in broiler rations (Leslie et al. 1973a; Olomu et al. 1974). In the latter experiments, it was noted that in some cases there was an increase in the weight of the heart and liver, but not the spleen, testes or pancreas of test birds. It was suggested that this might have resulted from the high levels of erucic acid in the seed. This suggestion was supported by further experiments in which broiler chicks were fed diets containing 20% ground Span (low erucic acid) RS or 20% ground and autoclaved Span RS (Olomu et al. 1975a). The results obtained confirmed the earlier findings that autoclaving reduced the goitrgenicity and improved the nutritive value of the seed. In this experiment neither autoclaved nor untreated seed, when comprising 20% of the diet, had any significant effect on liver size, although birds receiving the high dietary levels of autoclaved RS had leaner carcasses and larger heart sizes. The raw RS produced broiler chicks with consistently lower carcass-fat levels than did the autoclaved RS.

Bhargava and O'Neil (1978) reported the results of experiments in which broilers were fed diets containing heated full-fat Tower RS. Up to 15% of such seed was incorporated in the diet without adverse effects on body weight or feed consumption. However, a significant

depression in body weight occured with diets containing 20% RSM and histopathological examination revealed hyperplasia (unspecified) in chicks receiving this diet. Subsequent experiments involving finishing diets containing 0, 7, 14 or 21% heated Tower RS produced no pronounced effect on thyroid size, growth or carcass quality, although conflicting evidence was obtained regarding the effect of diet on feed efficiency.

The effect of using full-fat RS in layer diets was examined by Olomu et al. (1975b). A significant decrease in egg production and a significant level of hemorrhagic liver syndrome was observed, with increasing (0, 5, 10, 15%) levels of RS in the diet. The sizes of the heart and liver were unaffected by dietary treatments, although the high glucosinolate level of the seed had a clear effect in increasing the size of the thyroid gland. It was recommended that the inclusion of full-fat Span RS in the diet should be limited to 5% for laying hens. Slinger (1977), however, concluded that full-fat Tower RS could be given to broilers and laying hens at the 10% levels of inclusion with satisfactory results.

Other studies have been reported on the feeding value of full-fat CS for laying hens and broiler chicks. Robblee et al. (1983) suggested that CS may be used effectively as a high energy ingredient in wheat-based rations for laying hens to raise dietary energy content to desired levels. They found that at least 10% CS could be included without affecting mortality, rate of egg production, feed conversion, egg specific gravity or Haugh unit values.

In experiments with broilers, it was observed that raw, flaked CS could be used in broiler rations at a level of 10% to provide good growth rate and feed conversion and 'normal' mortality. However, when the level of CS was increased to 15 or 20% there was a decrease in growth rate, but mortality and feed conversion were not significantly affected.

Some of the detrimental effects previously observed with the older RS varieties may have been due to the higher levels of erucic acid found in them. Clement and Renner (1977) demonstrated that high erucic acid RS oils resulted in marked depressions in growth and poorer utilization of dietary energy but the newer low erucic acid oils resulted in no such depressions in bird performance.

Summers et al. (1982) found that CS fed to broilers at dietary levels of 17.5% or higher resulted in reduced weight gain and feed intake. However feed:gain ratios to 7 wks of age were similar. Nitrogen digestibility and amino acid supplementation studies appeared to rule out these factors as possible explanations for the poorer performance observed. Other trials reported by these authors suggested that palatability could be a contributing factor. It was also noted that apparent retention of dietary fat was significantly lower with CS as compared with corn-soya control diets; but whether this response was due to dietary fat levels per se, or was specific to CS oil could not be determined from these trials.

In feeding trials conducted with broiler chicks, Olomu et al. (1974) suggested that supplementation of diets containing raw ground whole RS with arginine or arginine and methionine improved growth and feed efficiency, although Summers et al. (1982) found that amino acid supplementation to diets containing raw ground CS did not improve growth rate or efficiency of feed utilization.

C. EXPERIMENTAL PROCESSING OF CANOLA RAPESEED

Based on data obtained from feeding trials using whole Tower RS, Leeson et al. (1978) suggested that whole RS could be effectivley used at levels of 10-20% in broiler diets and at levels of no more than 10% in the diets of laying hens. They further concluded that RS included in broiler diets should be heated before dietary inclusion, preferably by autoclaving, no advantage accrued when thus treated for laying hens. Shires et al. (1981) concluded that CS should be heated before feeding to broiler chickens. They suggested that autoclaved or extracted dehulled CS may be included in broiler diets at levels of 10% with no reduction in growth rate.

Heat treatment has also been reported to improve the nutritional value of low glucosinolate RS for mice (Josefsson and Munck 1972). Shires et al. (1981) suggested that the beneficial effect of autoclaving dehulled CS may be related in part to the disruption of cellular structure, (which would make the oil more accessible to digestive enzymes), in part to the destruction of glucosinolates, and in part to the inactivation of myrosinase.

Hill and Renner (1963), examined the effects of graded levels of heat treatment on ground soybeans and extracted dehulled soybean flakes and concluded that ME values of unheated samples were significantly lower than those of the optimally heated samples. Prolonged heating however, led to a decrease in energy values. They suggested that the absorbability of dietary fat was lower for unheated unextracted flakes, than when they were heated.

Srivastava and Hill (1976), examined the effects of mild heat treatment on *B. napus* cv. 940 (Tower) and cv. 1788 and obtained improved and depressed weight gains with heated and unheated samples, respectively when the RS was used as the only protein source for rats. They attributed the effect to the presence of unspecified palatability and appetite depressing factors in the unheated meals, a view also shared by Summers et al. (1982).

Josefsson (1975) suggested that some form of heat treatment of the seed or meal was necessary to produce a product with improved nutritional value even when the glucosinolate content was low. Appelqvist and Josefsson (1967) concluded that myrosinase activity was effectively destroyed by heat treatment when the seed's moisture content was 8% or more. While these and other studies demonstrate the effectiveness of heat treatment in improving the nutritional quality of both RS and CS, many of the methods utilized are experimental and did not lend themselves to practical, cost-effective use.

Several studies have been conducted to examine the effects of using steam pelleting and grinding to improve the nutritive value of CS for poultry (Bayley et al. 1968; Slinger et al. 1978; Shen et al. 1983) and for pigs (Narendran et al. 1979). Slinger et al. (1978) concluded that improvements in growth rates with pelleted versus mash diets containing whole, raw seed could be attributed to the heat treatment involved with the pelleting process. In other studies, Shen et al. (1983) proposed that CS could be used at up to 20% inclusion in steam-pelleted diets based on corn and SBM without altering broiler performance. They agreed with Josefsson's (1975) suggestion that some form of heat treatment was necessary to elicit maximal response from whole CS.

Narendran et al. (1979) using steam-pelleted RS diets fed to pigs, observed improved rates of gain and improved feed:gain ratios without increased feed intakes compared to diets containing untreated meal. They suggested that this effect may be due in part to improved palatability or improved digestibility of crude fiber.

The methods described thus far generally utilize some form of moist heat. The purpose of this study is however to examine the effects of dry heat on the nutrient availability of whole CS. The method used for heating the seed is that of jet-sploding using the California Pellet Mill Jet-Sploder™. The Jet-Sploder (Figure I.3), processes grains by subjecting them to super-heated air for a relatively short time period, followed by passage through a roller mill (Morrill 1984). The feedstuff is fed by gravity into a heat exchanger. Air heated to about 316°C is pumped through jets into the unit. After the desired time in the heat exchanger, the seeds are rolled. The temperature of the seed as well as the pressure developed by the super-heated moisture within the seed and the rollers are responsible for the changes that occur wihtin the seed. Control of the air flow system and the variable speed feeder ahead of the rollers result in the desired residency time for the seed to be in the heat exchanger and thus the desired internal temperature of the seed.

Morrill (1984) attributes several advantages to this system. Since moisture is not added in the process, it is not necessary to provide facilities for adding moisture nor to dry the processed product. The system is said to be very energy efficient since most of the air is recycled. In addition, the short residency time means that high production rates are possible.

Preliminary evidence suggests that trypsin inhibitor and urease can readily be destroyed in raw soybeans by the application of dry heat using the Jet-Sploder, (Whelan, unpublished). He found that heat treatment of ful-fat soybeans in the Jet-Sploder yielded higher ME values than the more expensive, time-consuming steam pelleting process (3.9 kcal/g DM vs. 3.7 kcal/g DM, respectively).

With these preliminary findings in mind, it was decided to adapt the jet-sploding process to the heat treatment of full-fat CS intended for broiler diets. It is hoped that this treatment would effectively inactivate myrosinase, thus eliminating the detrimental effects of

glucosinolate breakdown products, while at the same time rupturing the starch cells in the endosperm of the seed, making the oil more accessible to the digestive enzymes of the bird.

D. MEASUREMENT OF BIOAVAILABLE ENERGY IN CHICKEN FEEDS

Feed is the largest single cost in animal production, and for years accounted for 70-75% of poultry production costs (John 1976). A detailed analysis showed feed to be 67% of the cost of egg production when pullet rearing costs were included (Hill and Hunt 1980). Currently, feed probably accounts for 55-60% of poultry production costs, the reduction being associated with higher interest rates and increased fuel costs.

The bioavailable energy (BE) component of feed is about 70% of the cost; consequently BE accounts for approximately 40% of the 'farm gate' costs of poultry products. Reduction of BE input costs, through the use of more accurate BE values to estimate requirements and to formulate diets, offers the greatest potential for increasing production efficiency. Thus when one contemplates the analysis of a high energy feed ingredient such as full-fat CS for prospective use in chicken diets, the accurate measurement of BE becomes of the utmost importance.

Several statistics have been used as estimates of the BE contained in poultry feeds (Sibbald 1982). ME has become the generally accepted method of expressing feed values and energy requirements in poultry nutrition. The practical application of modern concepts of poultry feeding and diet formulation requires the accurate assessment of the ME values of diets and individual feedstuffs. In least cost formulation it is assumed that it is possible to assign a ME value to an ingredient independent of the nature of the diet in which it is supplied and that the values are additive.

Apparent metabolizable energy (AME) is the difference between gross energy (GE) in the food consumed and the GE in the feces and urine (National Research Council 1981):

AME=GE in food - GE in excreta

The term 'apparent' is used because the excreta contains energy which is not derived directly from the food, namely the metabolic fecal energy (FmE) and the endogenous urinary energy (UeE). The measurement of the true metabolizable energy involves the correction of the GE of the excreta for FmE and UeE losses:

TME=GE in food - [GE in excreta - (FmE + UeE)]

Both the AME and TME values may be corrected to zero nitrogen retention on the assumption that the oxidation of tissue protein will yield uric acid only, which has a GE/g of N of 8.22 kcal. Sibbald and Slinger (1962) used the factor of 8.73 kcal/g N as being more representative of the combustible energy of the urinary nitrogen excretory products. The effect on the results from using these different factors is however small. These nitrogen correction values are intended to reduce variations in the AME and TME values due to variation in retained nitrogen. It is generally assumed that AMEn and TMEn estimates are independent of retained nitrogen. The corrections of ME values for nitrogen gained or lost from the body during the assay also eliminates any variation in nitrogen associated with the age of the assay bird and the level of dietary protein.

E. OBJECTIVES

The objectives of these studies were:

1. To determine the economic impact of the inclusion of full-fat CS as a high energy feedstuff in the diets of laying hens where barley, wheat or corn form the sole cereal component.
2. To establish an optimal Jet-sploding temperature for improving the nutritive value of full-fat CS intended for use in broiler diets.
3. To examine the effects, if any, of Jet-sploding on the feeding value of full-fat CS for broiler chicks.

4. To estimate ME values for raw and optimally sploded full-fat CS for future use in least cost formulation of chicken rations.

F. EXPERIMENTS AT THE UNIVERSITY OF ALBERTA POULTRY RESEARCH FACILITY

Experiments were conducted to evaluate the nutritive value of full-fat CS in the diets of laying hens and to determine the effect of Jet-Sploding™ on the nutritive value of full-fat CS. The results are reported in the following chapters:

Chapter II.

Response of Laying Hens to Full-Fat Canola Seed Supplemented Diets Based on Barley, Wheat or Corn.

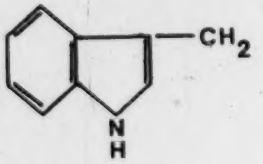
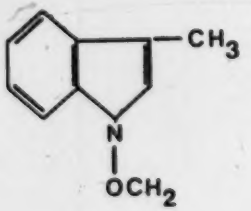
Chapter III.

Effect of Jet-Sploding at Different Temperatures on the True Metabolizable Energy and the Nutritive Value of Full-Fat Canola Seed for Adult and Broiler Chickens.

Chapter IV.

Evaluation of Jet-Sploding on the Apparent and True Metabolizable Energy Values of Full-Fat Canola Seed for Chickens.

Table I.1. Major Glucosinolates found in *Brassica napus* and *B. campestris* (canola) rapeseed.[1]

Glucosinolate	Semi-systematic name	R-group	Molecular Weight	
			Glucosinolate	Aglucone
Progoitrin	2-OH-3-butenyl-	CH_2=CH.CHOH.CH_2	428	266
Gluconapin	3-butenyl-	CH_2=CH(CH_2)$_2$	412	250
Glucobrassicanapin	4-pentenyl-	CH_2=CH(CH_2)$_3$	426	264
Napoleiferin	2-OH-4-pentenyl-	CH_2-CH.CH_2.CH.CH_2	442	280
Glucobrassicin	3-indolyl-methyl-		487	325
Neoglucobrassicin	1-methoxy-3-indolyl-methyl		517	355

[1]adapted from Bell, (1984).

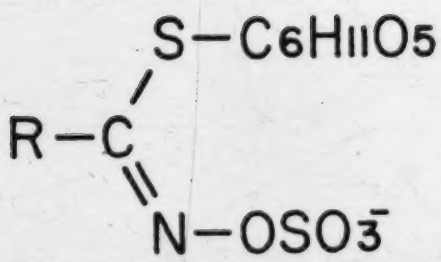
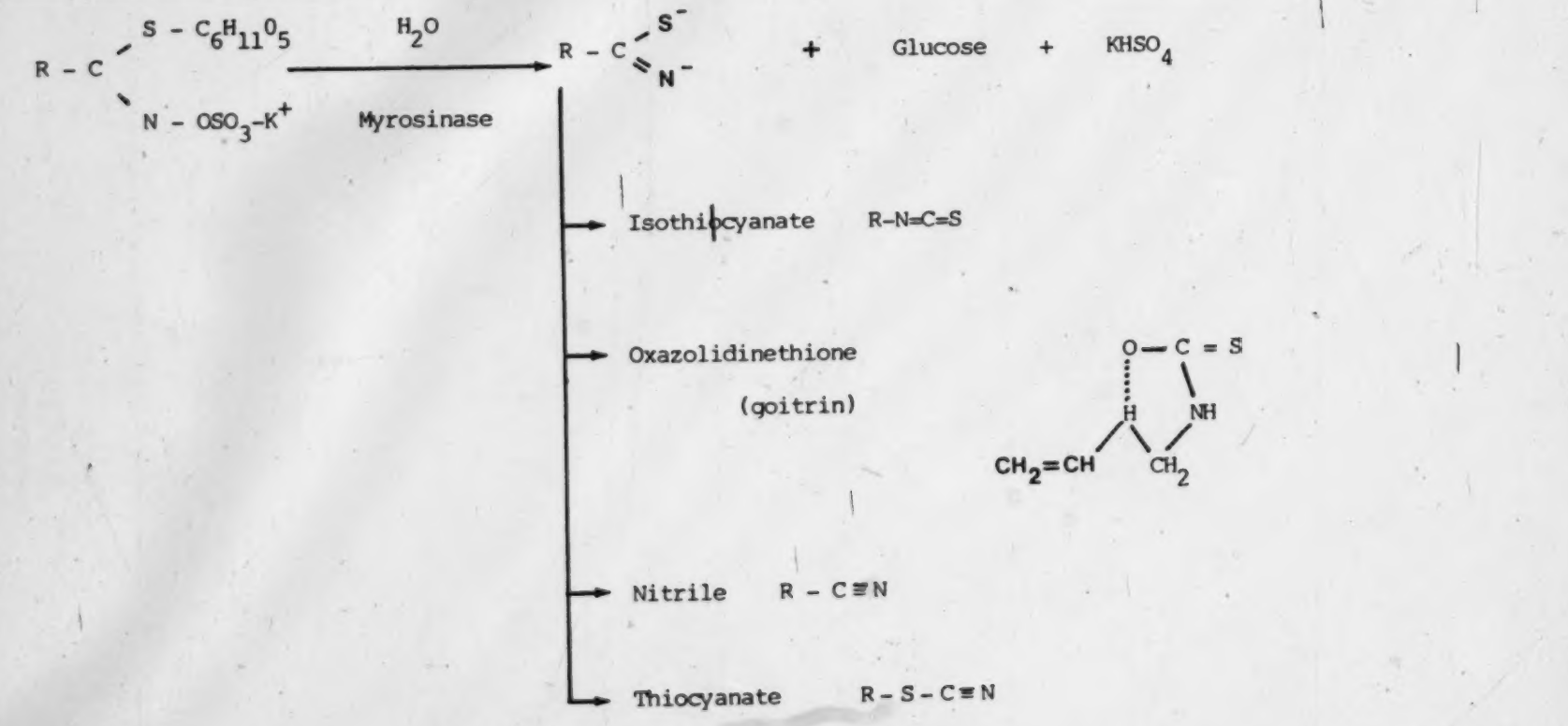


Figure I.1 General formula for glucosinolates.

Figure I.2 Autolysis products of glucosinolates in (canola) rapeseed.[1]



[1] adapted from Bell (1984).

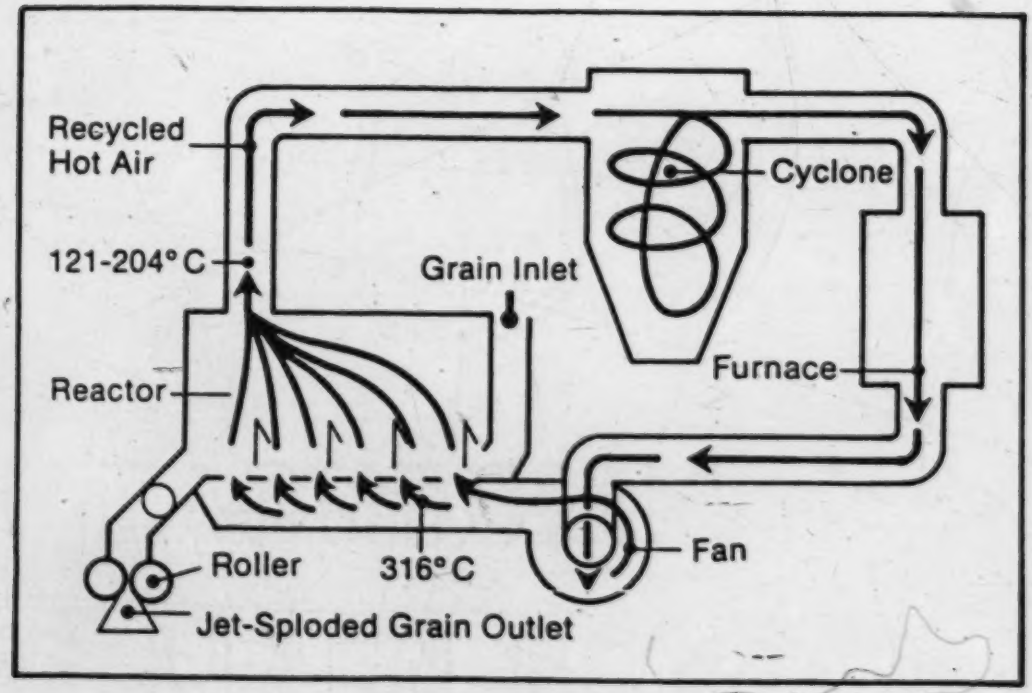


Figure I.3 Diagrammatic representation of the Jet-Sploding process.

(adapted from Morrill, 1984)

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II. Response of Laying Hens to Full-Fat Canola Seed Supplemented Diets Based on Barley, Wheat or Corn.

A. INTRODUCTION

The commercial production of canola seed (CS) in Alberta has increased rapidly in the last decade from 0.68 million hectares in 1975 to 1.17 million hectares in 1984, producing 1.29 million tonnes in that year (Statistics Canada 1984). The term Canola™ applies to the seed, meal, oil and other by-products of Canadian cultivars of RS which are low in glucosinolates and erucic acid. The crushing of CS produces two valuable products: 40% oil and a meal which contains close to 40% crude protein. Canola oil currently constitutes 55% of the edible non-animal based oil consumed in Canada. Occasionally in Canada, high grades of CS may become available to the poultry producer due to fluctuations in the economics of CS processing. Due to adverse climatic conditions in canola growing areas, 5-30% of the crop may be frost-damaged in any one year. Such frost-damaged CS is often available for animal feeding. Frost-damaged CS has a lower economic value because of reduced bushel weight, lower oil content and lower oil quality due to an increased chlorophyll content; this imparts a green color to the oil making it undesirable for human consumption, resulting in a lower priced product which may be used in animal rations. Considerable interest has been shown in this product by the Saskatoon research community, (Bell et al. 1985; Bell and Keith 1986) as a feed ingredient for pigs, but not much emphasis has been placed on its use as a feed ingredient for poultry.

A number of studies have been reported which show that canola meal (CM) can be used in laying diets to replace a substantial quantity of soybean meal (SBM) protein without any change in laying performance (Hulan and Proudfoot 1980; Clandinin et al. 1983; Summers 1983 and Summers et al. 1985). Based on such studies, a general recommendation for the use of up to 10% CM has been made for laying hen diets. While CM is now being used more extensively in laying hen diets, there still remains some controversy with regards to its nutritive value. There is some evidence to suggest that it may play a role in precipitating a

fatty liver and/or hemorrhagic liver condition with layers (Pearson and Butler 1978; Papas et al. 1979; Ibrahim et al. 1980; Hulan and Proudfoot 1981). However, there are probably an equal number of studies that indicate that no such liver problems were associated with the feeding of CM (March et al. 1975; Thomas 1978 and Proudfoot et al. 1983).

Fewer studies have been conducted to determine the nutritive value of CS for laying hens. With the high glucosinolate varieties of rapeseed (RS), adverse effects on performance characteristics have been reported (Leslie and Summers 1972; Leslie et al. 1973; Olomu et al. 1975 and Leeson et al. 1978). These effects were attributed to glucosinolate breakdown products. Heat treatment of RS to inactivate myrosinase enzyme was deemed essential by Woodly et al. (1972) if satisfactory performance was to be obtained when RS was fed to poultry. However, with the low glucosinolate, low erucic acid canola varieties, such heat-treatment of the seed may be unnecessary before incorporating CS into chicken diets. The need for grinding whole CS is also questioned, especially in diets containing grit, since the small-sized seed should be easily ingested and macerated by the bird. Both Leeson et al. (1978), working with RS, and Robblee et al. (1983), working with CS, have suggested that at least a 10% level of CS may be used as a satisfactory source of energy and protein in rations for laying hens.

Wheat, corn and to a lesser extent, barley, have been the cereal grains used most commonly as the major source of energy for laying hens in North America. Several studies have been conducted to evaluate the productive performance of hens fed diets of different cereal base over a complete laying cycle (Brown and Hale 1965; Sell 1971; Dunstan 1973; Campbell 1974; Sell and Johnson 1974). In these experiments, no significant differences were noted among diets with regard to total egg production. These data indicate that laying hens are capable of maintaining a high rate of production when fed barley- or wheat-based diets. However, due to their low energy densities it is necessary to add fat to such diets to raise their energy content to desired levels. Since CS contains approximately 42% ether extract and 20-23% protein, it would appear to be a potentially excellent source of high quality protein and energy, especially in barley and wheat-based diets.

The objectives of this study were therefore to determine the effects of supplementing diets containing ground corn, wheat or barley as the sole cereal ingredient with 0 and 10% whole CS on the biological and economical performance of laying hens.

B. MATERIAL AND METHODS

This experiment was conducted at the University of Alberta Poultry Unit for a period of 44 wks between November 1984 and September 1985. In the experiment, 768 Single Comb White Leghorn (SCWL) pullets (Shaver Starcross 288) were brooded and reared in floor pens. At 20 wks of age they were placed at random in double deck, stair-stepped laying cages (42cm x 32cm) with 2 birds per cage, thus providing a floor area of 672 cm^2/bird. All birds were weighed at 20 wks of age. Daylength at the start of the experiment was 10.5 hrs and was increased weekly until a maximum of 16 hrs was achieved at 31 wks of age and was maintained at that level for the duration of the experiment. The birds were fed a growing ration (15% CP) until 22 wks of age at which time they were assigned to the experimental diets (Table II.1).

The diets were formulated to provide a fixed calorie-protein ratio and were neither isoenergetic nor isonitrogenous. The diets were based on either barley, wheat or corn as the sole cereal grain and were supplemented with either 0% or 10% Canada Grade 1 full-fat CS (*Brassica campestris* cv. Tobin). All diets were supplemented with 5 kg of granite grit (hen-sized, #3) per 100 kg of diet.

Each diet was fed ad libitum to four replicates of 32 hens for a period of 308 days. Data was collected on daily mortality, daily egg production, monthly feed consumption (monthly replicate average), and egg weights (the average weight of eggs laid by each replicate and collected on 2 consecutive days of each week). Eggs from each replicate were also graded by weight in accordance with the grades and standards for Canada Grade A eggs as outlined in the Canada Agricultural Products Standards Act (1974).

All derived incomes were based on the producer paying prices issued weekly by the Alberta Egg Marketing Board, Calgary, Alberta. The relative costs of the diets were estimated

with the following prices of ingredients in Can$/tonne: canola seed, 250; soybean meal, 310; barley, 101; corn, 180; and wheat, 129. Total income for each dietary treatment was based on the egg incomes received from eggs sold over the 44 wk trial period and from that obtained from the sale of spent birds at the end of the trial. Feed costs (Table II.6) were based on the overall feed consumption of the four replicates/treatment (in tonnes) and the cost/tonne of each of the 6 diets. Any birds that died during the trial were sent to a veterinary laboratory (Alberta Agriculture, Animal Health Division, O.S. Longman Bldg., Edmonton, Alberta) for autopsy.

Statistical Analysis

All data was subjected to 2-way analysis of variance (anova) with three cereal factors- barley, wheat and ground corn, and two canola factors - 0% and 10% levels of inclusion. Where appropriate, treatment means were tested for significance ($P<0.05$) using the Student-Newman-Keuls (SNK) multiple range test when preceded by a significant F-test, (Steel and Torrie 1980). All statistical calculations were performed using the Statistical Package for the Social Sciences X, (SPSSX).

C. RESULTS

A summary of the results from the six dietary treatments is presented in Table II.2. The effects of cereal base and canola inclusion are presented in Tables II.3 - II.6. Although differences in the level of mortality of birds fed the various diets did not reach statistical significance, the cumulative mortality was highest for the corn-based diets (7.8%) and lowest for the wheat-based diets (4.3%). The largest cause of mortality was due to lymphoid leukosis virus, (46% of reported cases), followed by cannibalism (15%) and hemorrhagic liver syndrome (9%). The remaining deaths (30%) were attributed to miscellaneous causes. There were only four cases of hemorrhagic liver syndrome , two from birds which were fed diet 6 and one from each of the groups fed diets 1 and 5. There was a trend for mortality to be greater for birds fed diets containing 10 compared to those fed 0% CS (5.2 vs. 7.0%

mortality), but the difference was nonsignificant ($P>0.05$).

Egg production expressed in terms of % hen-day, % hen-housed, eggs/hen-housed or eggs/hen-day was not significantly affected by dietary treatments. Feed intake expressed in terms of grams of feed/hen-day was significantly lower for birds fed the corn-based ($P<0.05$) as compared to barley and wheat-based diets. A significant decrease in feed intake was also noted with diets containing 10% CS as opposed to canola-free diets, ($P<0.05$).

Feed efficiency expressed in terms of eggs produced and live weight gain were significantly greater for birds fed the corn-based diets ($P<0.05$) than for those fed either barley or wheat-based diets. Similarly, hens fed diets containing 10% CS had lower feed:gain ratios than those fed diets containing 0% CS ($P<0.05$). There was a significant trend ($P<0.05$) towards increased live weight gains for birds fed corn and wheat-based diets, with barley-based diets producing the lowest average live weight gain (404.5g for the 44-wk trial period). There was a slight but nonsignificant increase in average live weight gains of birds fed diets containing 0% CS as compared to those fed diets supplemented with 10% CS. Initial live weights recorded at 20 wks of age were not significantly different between treatment groups indicating that the observed differences in body weight gain could be attributed to dietary effects.

There was a significant ($P=0.025$) 2-way interaction between the level of CS used and body weight gain. The barley diet containing 10% CS resulted in a slight increase in weight gain as compared to the barley diet without CS (389.3g vs. 419.8g, respectively). However, for birds fed the wheat and corn-based diets containing 10% CS, there were significant ($P<0.05$) decreases in average body weight gain as compared to birds fed similar diets without CS, 571.8g vs. 495.5g and 573.8g vs. 557.3g for the wheat and corn-based diets, respectively. These results suggest that the effects of addition of 10% CS may be influenced by the grain source used in the diet.

Birds fed the corn-based diets produced larger ($P<0.05$) eggs than those fed the wheat-based diets, (60.3g vs. 59.3g). The birds fed the barley-based diets laid eggs of intermediate average egg weights (59.6g). Egg weight was not significantly affected by

supplementary CS in the diet.

There were significant differences in feed costs between treatment groups which were a direct reflection of the feed consumption and the cost of individual dietary ingredients. Barley-based diets cost significantly less than either wheat or corn-based diets ($P<0.05$), with corn-based diets being the most expensive. Consequently, net income was highest for birds fed the barley-based diets despite the poorer performance observed with these grains. Income was not significantly affected by the addition of CS to the diet.

D. DISCUSSION

There are numerous studies in the literature indicating that wheat and barley may be used in diets for laying hens with satisfactory results (Arscott and Rose 1960; Anderson and Wagstaff 1960; Brown and Hale 1965; Lillie and Denton 1968; Sell 1971; Dunstan 1973 and Campbell 1984). These grains will normally support egg production equal to that obtained with corn-based diets. There are, however, a number of considerations which must be taken into account when using barley and wheat in laying hen diets. Firstly, barley and wheat have different nutrient contents to corn. In comparison to corn, barley is considerably lower and wheat slightly lower in metabolizable energy. Furthermore, there is a greater variability in the nutrient content of barley and wheat as compared to corn.

Barley, however, contains more total protein (11-15% CP, DM basis) and higher levels of lysine, tryptophan, methionine and cystine than does corn (NAS-NRC 1984), but the higher fiber content tends to limit its use in poultry rations. Hulless varieties of barley are roughly equivalent in energy to wheat and corn and seem to be more suitable for poultry feeding. Classen et al. (1985) reported that the true metabolizable energy (TME) value of hulless barley was significantly higher than for hulled barley and was similar to that of wheat for adult roosters (15.23 ± 0.13 KJ/g vs 14.53 ± 0.21 KJ/g), (3.64 kcal/g vs 3.47 kcal/g, respectively). They concluded however, that despite a high TME, hulless barley was not a suitable cereal source for chicks because of fat malabsorbtion and inadequate vitamin D_3 absorbtion.

With regard to the protein content of corn, 73% of the total protein is found in the endosperm and 24% in the embryo. The latter is of higher quality and is composed of a mixture of glutelin, globulins, albumens and other proteins (Church 1984). The principle protein in the endosperm is zein, a relatively insoluble protein which comprises about half of the total kernel protein. This protein is low in several of the essential amino acids, particularly lysine and tryptophan; as a result, corn-based diets for monogastric animals often require supplementation to produce adequate performance. In addition, the low tryptophan content, (which is a precursor of niacin), plus the low niacin content, will lead, eventually to a niacin deficiency and pellegra in monogastric animals dependent on corn as a major dietary constituent.

The amino acid (AA) distribution of wheat is more favourable than that of corn, especially for lysine, tryptophan, methionine, cystine and histidine (Church 1984; NAS-NRC 1984). Soft wheats are generally lower in the essential AAs (as %DM) than corn, but are a much better source of AAs than corn, with the exception of tryptophan. As an energy source, wheat does not produce as rapid a growth rate with poultry as does corn, but it very frequently produces more efficient growth than does corn (Church 1984). If fed in large amounts however, finely ground wheat tends to form a pasty mass on the beaks of birds.

In this study there were no significant differences ($P>0.05$) in egg production between layers fed either barley, wheat or corn-based diets. Arscott and Rose (1960) observed no differences in egg production with either White Leghorn or New Hampshire layers fed barley or corn-based diets. Hens fed the barley and wheat-based diets in the present study required significantly more feed ($P<0.05$) to produce a dozen eggs than did birds fed corn-based diets, an observation which was also reported by Anderson and Wagstaff (1960). This was to be expected, however, because laying hens will adjust feed intake to compensate for lower dietary energy levels. As a result, most trials have shown that when barley is used as the sole cereal grain, there is greater feed intake and consequently more feed required per dozen eggs as opposed to comprable wheat-based diets (Anderson and Wagstaff 1960; Arscott and Rose 1960).

Lockhart and Bryant (1965) reported that laying hen diets containing barley as the only cereal grain supported egg production equally as well as corn-based diets but were less efficient. In diets containing 16% CP, corn-based diets resulted in 75.3% egg production and barley-based diets 78.0%. These authors reported feed efficiencies of 3.90 and 4.14 lb of feed/doz eggs (1.76 and 1.86 kg feed/doz eggs) for the corn and barley-based diets, respectively. At 14% CP, egg production was 78.0% for corn and 77.6% for barley-based diets. Feed efficiencies were 3.93 and 4.24 lb feed/doz eggs (1.77 and 1.91 kg feed/doz eggs), respectively Brown and Hale (1965) reported similar results. Their results are in close agreement with the estimates obtained in the present study, (1.77 and 1.86 kg feed/doz eggs) for corn and barley-based diets, respectively. Barley-based hen-housed and hen-day production (15% CP) averaged 76.37 and 76.35%, respectively whereas corn-based hen-housed and hen-day production (18% CP) averaged 75.65 and 79.35%, respectively.

Sell and Hodgson (1966) obtained 72.2% egg production for a 308 day experiment with a wheat-soybean meal ration containing 13.5% CP, whereas hens fed a ration containing 16.5% CP produced at a rate of 78.2%. In comparison the wheat-based diets used in this study contained 17.3% CP and resulted in hen-housed and hen-day production rates of 76.93 and 78.41% respectively. Lillie and Denton (1968) reported similar egg production estimates for 12.5 and 15% CP diets based on corn, wheat and barley.

Campbell (1984) summarized data obtained in several experiments comparing barley, wheat and corn-based diets. Egg production, feed consumption and representative egg weight data were used to calculate feed efficiency values for each of the treatment comparisons. It was concluded that corn-based diets were superior to wheat-based diets, which in turn, were superior to barley-based diets in terms of the amounts of feed required to produce a given egg weight. In this experiment, corn-based diets resulted in significantly greater ($P=0.014$) average egg weights than wheat-based diets (60.33 vs 59.25 g). Barley-based diets, however, produced eggs of intermediate egg weight (59.58g) which is contrary to Campbell's (1984) results.

The cereal based diet yielding the best feed efficiency, however, need not necessarily be the most judicious choice from an economic standpoint. A comparison of the efficiency of feed utilization for egg production may be complicated by a differential response in egg size. The proportion of eggs alloted by weight to the Canada Grade A categories is of importance since the differential in prices among the categories could have a marked influence on the overall economic analysis of a particular cereal-based diet. It is of interest to note that from June 4, 1985 until the completion of the experiment on September 3, 1985, there was no price differential between Canada Grade A extra large and large eggs as set by the Alberta Egg Marketing Board. Both categories fetched a price of $1.02 per dozen eggs. In addition, large egg size may have a detrimental influence on shell quality.

Although the data in the literature regarding the influence of various cereal-based diets on egg weight is inconclusive, the results of the trial reported herein indicate a trend towards a greater number of extra-large eggs laid by hens receiving the highest level of linoleic acid (corn-based diets), and conversely a trend towards fewer medium eggs in this treatment group as compared to the diets with lower levels of linoleic acid. There was a significant ($P<0.05$) trend for birds fed the wheat-based diets to produce a greater percentage of Canada Grade A medium eggs as opposed to those fed barley and corn-based diets (32.85 vs 30.57 and 26.35g respectively). Balnave (1971) demonstrated that linoleic acid was the major constituent responsible for the beneficial effect on egg weight when laying hen diets were supplemented with corn oil. More recently, Whitehead (1981) reported that laying hens do not respond in terms of increases in egg weight to levels of linoleic acid above 0.9% of the diet but do respond to an increase in the dietary amount of readily absorbable fatty acids. The reason for the observed trend of larger eggs from wheat-based diets is not clear but may be related to dietary energy density.

There is more phosphorous (P) in barley and wheat than in corn and there is some indication that the P is more available. This is substantiated in work by Hayes et al. (1979) with chicks. They reported the biological availability of P in corn, hard wheat, soft wheat and barley at 12, 43, 58 and 50% respectively. According to their data the available P content of

corn is 0.03% as compared to 0.22, 0.16 and 0.17% in barley, hard winter wheat and soft winter wheat, respectively. This greater P availability in barley and wheat is not due to the fact that these grains contain less phytin P, but rather that barley and wheat contain higher levels of natural phytase. Although the effect of age on the ability of poultry to utilize phytate P has not been clearly defined, there are data indicating that the utilization of phytin P increases with age to maturity (Nelson 1967).

Initial body weight of the pullets (140 days of age) averaged 1.45 kg. Campbell (1984) noted similar initial weights using SCWL Shaver 288A hens weighed at 150 days of age. Hens fed corn and wheat-based diets gained significantly more weight (565.5 and 533.6 vs 404.5g) than hens fed barley-based diets during the course of the experiment, but this had no effect on the income received from spent birds.

Egg production was not adversely affected ($P>0.05$) by the inclusion of 10% Tobin CS, when used as a high energy and high protein source in barley, wheat and corn-based diets. Leslie and Summers (1972) using *B. campestris* cv Echo RS incorporated into isocaloric isonitrogenous diets at levels of 0, 5, 10 and 15% and fed to Starcross SCWL hens, observed decreased production with diets containing 15% unprocessed RS. No treatment effect ($P>0.05$) was noted with respect to any of the parameters of egg quality, with the exception of egg weight, which decreased with increased levels of RS in the ration. This difference in response in the experiments may be due to the low levels of total glucosinolates and erucic acid found in *B. campestris* cv Tobin as opposed to the higher levels of these compounds present in Echo RS.

Robblee et al. (1983) using isocaloric, isonitrogenous diets conaining 0, 5, 10 and 15% whole CS, observed that the treatments had no effect on bird mortality, rate of egg production, feed conversion, egg specific gravity or Haugh unit values. Mortality was not affected by the level of dietary inclusion of CS.

Some authors have suggested that birds fed high glucosinolate whole RS produced smaller eggs (Summers et al. 1969; Leslie and Summers 1972; March et al. 1975; Leeson et al. 1978; Summers et al. 1985). However, Olomu et al. (1975) found that inclusion rates up to

15% whole RS had no effect on egg weight. In the present trial, the inclusion of 10% CS in layer diets had no effect on average egg weight as compared to diets without CS, (59.60 vs 59.75g, respectively).

Summers et al. (1985) have suggested that 10% CM can be substituted for a similar quantity of soybean meal (SBM) protein in layer diets, with little or no alteration in performance. It would appear that one of the main factors leading to reduced performance when CM substitutes for SBM protein is a lowering of the energy density in the diet. While one would expect that with a lower level of dietary energy the hen would consume more feed to maintain a similar intake of energy, often this does not occur. Reduced feed intake with CM and/or RSM-containing rations has been reported for poultry (Slinger et al. 1978; Summers et al. 1978) as well as for young pigs (McKinnon and Bowland 1977). Reduced feed intake with CM and/or RSM has been shown to be associated with glucosinolate levels in the meal (Lee et al. 1984). While the glucosinolate levels in canola have been substantially reduced, there still is a small percentage in the meal (Bell et al. 1981) and seed, and hence this may account for the slightly lower feed intake noted with some diets containing CM and CS.

The significantly ($P<0.05$) reduced feed intakes observed for CS-containing diets (116.3 vs 121.2g/hen-day respectively) may be due to the effect of glucosinolates or their breakdown products. However, since a similar effect was observed with corn-based diets as contrasted with barley and wheat-based diets (114.82 vs 121.15 and 120.24 g/hen-day respectively), the reduced feed intake is probably due to the increased energy density in diets containing corn or supplementary CS. Birds fed higher energy diets tend to reduce feed consumption.

E. SUMMARY

The results obtained in this trial indicate that 10% CS can be effectively used as a high energy, high protein source to improve low energy density diets based on wheat and barley, without affecting profitability.

Table II.1. Composition of experimental diets.

Ingredients	0% CS			10% CS		
	Barley	Wheat	Corn	Barley	Wheat	Corn
	(%)					
Ground barley	72.2	-	-	62.0	-	
Ground wheat	-	68.6	-	-	59.1	
Ground corn	-	-	60.9	-	-	52.7
Canola seed	-	-	-	10.0	10.0	10.0
Soybean meal (47%)	15.0	17.8	25.0	15.0	17.0	23.0
Dehy. alfalfa meal	2.0	2.0	2.0	2.0	2.0	2.0
Biofos	1.3	1.3	1.3	1.3	1.3	1.3
Limestone grit	7.2	8.0	8.0	7.4	8.3	8.7
Iodized salt	0.3	0.3	0.3	0.3	0.3	0.3
Layer micromix[a]	2.0	2.0	2.0	2.0	2.0	2.0
Cost, ($/tonne)	185.00	209.00	254.00	196.00	216.00	255.00
Calculated Analysis						
Protein, %	15.0	17.0	17.9	16.0	17.6	18.3
ME, kcal/kg	2300	2600	2730	2430	2690	2800
ME/Protein	153	153	153	152	153	153
Calcium, %	3.03	3.36	3.55	3.15	3.50	3.65
Total P, %	0.63	0.64	0.60	0.65	0.66	0.62
Avail. P, %	0.38	0.38	0.37	0.39	0.39	0.38
Lysine, %	0.75	0.82	0.91	0.84	0.89	0.96
Methionine, %	0.28	0.31	0.35	0.31	0.33	0.37
Met. + Cys., %	0.53	0.61	0.62	0.58	0.65	0.65

[a]Premix provided per kg diet: 8,000 IU vitamin A; 1,200 ICU vitamin D_3; 5 IU vitamin E; 4 mg riboflavin; 6 mg d-calcium pantothenate; 15 mg niacin; 10μg vitamin B_{12}; 100 mg choline chloride; 100 μg d-biotin; 500 mg DL-methionine; 108 mg manganese ($MnSO_4.4H_2O$; 72 mg zinc (ZnO); 125 mg ethoxyquin.

Table II.2. Summary of results derived from laying hens during a 44 wk laying trial.

	0% CS			10% CS			SEM	SIG
	Barley	Wheat	Corn	Barley	Wheat	Corn		
Cumulative Mortality (%)	5.47	4.69	5.47	7.03	3.91	10.61	2.04	NS
Egg Production								
Hen-housed (%)	76.55	75.58	76.36	76.20	78.29	74.94	1.66	NS
Hen-day (%)	79.23	77.61	79.09	79.48	79.22	79.62	1.27	NS
Eggs/hen-housed	235.77	232.78	235.19	234.69	241.13	230.81	5.10	NS
Eggs/hen-day	243.96	238.96	243.56	244.62	244.09	245.28	3.96	NS
Feed Intake (g/hen-day)	123.22^{a}	122.45^{a}	117.83^{b}	119.08^{b}	118.05^{b}	111.81^{c}	0.73	•
Feed Efficiency								
(kg feed/doz eggs)	1.90^{a}	1.92^{a}	1.84^{a}	1.82^{ab}	1.82^{ab}	1.71^{b}	0.03	•
(kg feed/kg gain)	2.74^{ab}	2.80^{a}	2.60^{b}	2.64^{b}	2.64^{b}	2.45^{c}	0.04	•
Average Live wt. gain, (g/bird)	389.25^{a}	571.75^{c}	573.75^{c}	419.75^{a}	495.50^{b}	557.25^{c}	17.76	•
Average initial weights, (g/bird)	1452.75	1436.00	1459.25	1466.50	1442.75	1446.75	10.85	NS
Average egg weight, (g/egg)	59.70^{ab}	58.80^{a}	60.75^{b}	59.45^{ab}	59.45^{ab}	59.91^{ab}	0.37	•
Egg income, ($/hen-housed)	17.29	17.06	17.60	17.32	17.81	17.11	0.35	NS

• Statistical significance at $P<0.05$.
NS Nonsignificant ($P>0.05$).
a,b,c Values in the same line with the same letters or no letters are not significantly different as determined by the Student-Newman-Keuls test at ($P<0.05$).
SEM, standard error of a treatment mean of 4 replicates.

Table II.3. Effect of supplementing barley-, wheat- and corn-based diets with 0% and 10% full-fat canola on the performance of laying hens from 22 wks to 66 wks of age.

	Cereal Effects					Canola Effects			
	Barley	Wheat	Corn	SEM	SIG	0%	10%	SEM	SIG
Cumulative Mortality (%)	6.25	4.30	7.81	1.44	NS	5.21	7.03	1.18	NS
Egg Production									
Hen-housed (%)	76.37	76.93	75.65	1.17	NS	76.16	76.47	0.96	NS
Hen-day (%)	76.35	78.41	79.35	0.90	NS	78.64	79.44	0.73	NS
Eggs/hen-housed	235.23	236.95	233.00	3.61	NS	234.58	235.54	2.95	NS
Eggs/hen-day	244.29	241.52	244.42	2.80	NS	242.16	244.66	2.29	NS

NS Nonsignificant ($P>0.05$)
SEM, standard error of treatment mean of 8 (cereal) and 12 (canola) replicates, respectively.

Table II.4. Effect of supplementing barley-, wheat- and corn-based diets with 0% and 10% full-fat canola on egg size based on weight classes of laying hens from 22 wks to 66 wks of age.

	Cereal Effects					Canola Effects			
	Barley	Wheat	Corn	SEM	SIG	0%	10%	SEM	SIG
Egg size (% total eggs)									
Extra large	26.18	23.40	30.47	2.05	NS	27.30	26.07	1.67	NS
Large	40.81	40.95	41.04	0.80	NS	41.02	40.86	0.66	NS
Medium	30.57^{ab}	32.85^{a}	26.35^{c}	1.59	*	29.18	30.63	1.30	NS
Small	2.31	2.59	1.94	0.05	NS	0.18	0.20	0.04	NS
Pee-Wee	0.19	0.20	0.19	0.05	NS	0.18	0.20	0.04	NS

Extra large, 64-72 g; Large, 56-64 g; Medium, 49-56 g; Small, 42-49 g; Pee-Wee, <42 g;
* Statistical significance at $P<0.05$.
NS Nonsignificant ($P>0.05$).
a,b,c Values in the same line with the same letters or no letters are not significantly different as determined by the Student-Newman-Keuls test at ($P<0.05$).
SEM, standard error of treatment mean of 8 (cereal) and 12 (canola) replicates, respectively.

Table II.5. Effect of supplementing barley-, wheat- and corn-based diets with 0% and 10% full-fat canola on feed intake, feed efficiency, live weight gain and egg weight of hens from 22 wks to 66 wks of age.

	Cereal Effects					Canola Effects			
	Barley	Wheat	Corn	SEM	SIG	0%	10%	SEM	SIG
Feed intake (g/hen day)	121.15[a]	120.24[a]	114.82[b]	0.52	•	121.16[e]	116.31[f]	0.42	•
Feed efficiency,									
(kg feed/doz eggs)	1.86[a]	1.87[a]	1.77[b]	0.02	•	1.88[e]	1.78[f]	0.02	•
(kg feed/kg gain)	2.69[a]	2.72[a]	2.53[b]	0.03	•	2.71[e]	2.57[f]	0.02	•
Average Live wt. gain, (g/bird)	404.50[a]	533.63[b]	565.50[b]	12.56	•	511.58	490.83	10.26	NS
Average initial weights (g/bird)	1459.63	1439.38	1453.00	7.67	NS	1449.33	1452.00	6.27	NS
Average egg weight (g/egg)	59.58[ab]	59.25[a]	60.33[b]	0.26	•	59.75	59.60	0.21	NS

• Statistical significance at $P<0.05$.
NS Nonsignificant ($P>0.05$).
a,b Values in the same line with the same letters or no letters for Cereal Effects are not significantly different as determined by the Student-Newman-Keuls test at ($P<0.05$).
e,f Values in the same line with the same letters or no letters for Canola Effects are not significantly different as determined by the Student-Newman-Keuls test at ($P<0.05$).
SEM, standard error of treatment mean of 8 (cereal) and 12 (canola) replicates, respectively.

Table II.6. Effect of supplementing barley-, wheat- and corn-based diets with 0% or 10% full-fat canola on income derived from laying hens during a 44 wk laying trial.

	Cereal Effects					Canola Effects			
	Barley	Wheat	Corn	SEM	SIG	0%	10%	SEM	SIG
Gross Egg Income ($/bird)	17.39	17.43	17.35	0.25	NS	17.37	17.41	0.20	NS
Income from spent birds ($/bird)	0.24	0.25	0.25	0.01	NS	0.25	0.24	0.004	NS
Feed costs ($/bird)	6.90[a]	7.78[b]	8.63[c]	0.08	•	7.78	7.76	0.07	NS
Net Income ($/bird)	10.73[a]	9.91[b]	8.97[c]	0.19	•	9.84	9.89	0.16	NS
Egg Income, ($/hen-housed)	17.30	17.43	17.35	0.25	NS	17.31	17.41	0.20	NS

• Statistical significance at $P<0.05$.
NS Nonsignificant ($P>0.05$).
a,b,c Values in the same line with the same letters or no letters are not significantly different as determined by the Student-Newman-Keuls test at ($P<0.05$).
SEM, standard error of treatment mean of 8 (cereal) and 12 (canola) replicates, respectively.

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III. Effect of Jet-Sploding at Different Temperatures on the True Metabolizable Energy and the Nutritive Value of Full-Fat Canola Seed for Adult and Broiler Chickens.

A. INTRODUCTION

Full-fat canola seed (CS) is periodically available as a potential feed ingredient for poultry rations. Such samples may be either frost-damaged, off-grade seeds unsuitable for oil extraction, or higher grade samples available due to fluctuations in the economics of oilseed processing. CS contains approximately 40% oil and 20-23% protein.

With dietary inclusions of high glucosinolate varieties of rapeseed (RS), adverse effects on performance characteristics of both laying hens (Leslie and Summers 1972; Leslie et al. 1973; Olomu et al. 1975) and broiler chickens (Leslie et al. 1973; Olomu et al. 1975a) are well documented. Summers et al. (1982) suggested that feeding levels in excess of 17.5% CS (low glucosinolate RS) to broiler chickens depressed growth rates and feed intakes up to 7 weeks of age; dietary fat utilization was also depressed. Some of the conflicting reports concerning the value of full fat RS for poultry may be due to the fact that the level of erucic acid in the seed varied depending on the cultivar. Clement and Renner (1977) demonstrated that high erucic acid RS oils resulted in marked depressions in growth and poorer utilization of dietary energy while the newer low erucic acid canola oil resulted in no such depression in bird performance.

The poor performance characteristics observed with RS have been attributed to glucosinolate breakdown products brought about by active myrosinase in the seed, (Fenwick and Curtis 1980; Bell 1984). It has been shown, however, that high temperature heat treatment quickly destroys the myrosinase enzyme, thus eliminating or reducing the growth inhibiting properties of RS (Belzile et al. 1963; Woodly et al. 1972). Jossefson (1975) suggested that some form of heat treatment was necessary to produce a product with improved nutritional value even when the glucosinolate content is low.

Commercially, steam pelleting and subsequent grinding (Bayley et al. 1968; Slinger et al. 1978; Shen et al. 1983), have been used to improve the nutritional quality of CS intended

for use in broiler diets. This method of processing however, requires the application of both moisture and heat. Alternatively, the California Pellet Mill has developed the Jet Sploder™ process which negates the need and expense of added moisture (Morrill 1984). 'Jet-Sploding' is a process which utilizes high temperature for a short period of time. The feedstuff is fed by gravity into a heat exchanger. Air heated to about 316°C and pumped through jets into the chamber of the heat exchanger, rapidly heats the seed and transports it through the unit. As the seed containing superheated moisture at high pressure leaves the unit it passes through a roller which 'pops' or 'explodes' the seed. The length of time the seed is allowed to remain in the heat exchanger controls the internal temperature of the seed. Temperature probes in the path of the circulating seeds within the heat exchanger are used to determine the final temperature of the seeds. Morrill (1984) attributed several advantages to this system. Since moisture is not added in the process, it is not necessary to provide the facilities for adding moisture nor to dry the processed product. The system is said to be very energy efficient since most of the air is recycled. In addition, the short residency time means that high production rates are possible.

Preliminary evidence with soybeans suggested that trypsin inhibitor and urease enzyme can be readily destroyed by the application of dry heat using the Jet-Sploder. However, to date, no investigation has been conducted on the effectiveness of the process on reducing or eliminating myrosinase activity in full-fat CS or on the effect of sploding on the nutritive value of CS for broiler chickens.

The determination of metabolizable energy (ME) provides a means for determining the overall utilization of a diet or dietary component (De Groote 1974). It measures the metabolic sum of the processes of digestion, absorption and utilization of a diet in energy units. In the chicken, ME is the difference between the gross energy (GE) in the food consumed and the GE in the feces and urine. The measurement of true metabolizable energy (TME) involves the correction of the GE of the excreta for the metabolic fecal energy (FmE) and the endogenous urinary energy (UeE) losses. The TME assay has been found to be a highly precise measure of the available dietary energy for the chicken and a useful tool for

quantitative studies of energetic relationships in growth.

Part of the ME is retained in the body as protein which may be degraded and excreted in the form of uric acid. The correction of ME values (TMEn) for nitrogen gained or lost from the body during the assay eliminates the variation in nitrogen retention associated the age of the assay bird and the level of dietary protein. The correction for nitrogen retention is made on the assumption that the oxidation of tissue protein will yield uric acid only, which has a GE/g N of 8.22 kcal (Miller 1974).

It was decided to apply the TMEn method to the quantitative evaluation of the effects of heat treatment on full-fat CS as an indication of overall energy utilization. The objectives of this study were therfore:

1. To establish a representative TMEn value for full-fat CS.
2. To evaluate the effect of the Jet-Sploding process on the TMEn of full-fat CS.
3. To establish an optimal temperature for Jet-sploding full-fat CS using both the TME bioassay and by incorporating both raw and heat-treated CS in broiler rations.

B. MATERIALS AND METHODS

Test Ingredients

Samples of raw Canada Grade 1 Tobin CS (*B. campestris*) were sent to the California Pellet Mill, Crawfordsville, Indiana, for processing in the Jet-Sploder. Based on previous results obtained with whole soybeans, a temperature range of 240-360°F (116-182°C) was used to process ten batches of CS. In so doing, it was hoped, based on the results obtained from the TMEn trial, to be able to select an optimal temperature for jet-sploding CS. After sufficient heating in the heat exchanger of the Jet-Sploder, the CS samples were passed through rollers with an aperature of @1mm. Raw CS was used as a control.

Assay for TMEn

Thirty-six adult male egg type (Shaver Starcross 288) chickens were used to measure the TMEn values of the test ingredients by the method of Sibbald (1976, 1983). The birds were housed singly in alternate cages, (providing a floor area of 1151cm²)/bird, to minimise the cross-contamination of excreta. Water was provided ad libitum via water cups. Feçal samples for individual birds were collected in trays placed under the wire screen floors of the cages. Artificial lighting of the room was controlled automatically to provide 14 hrs of light and 10 hrs of darkness. Room temperature was maintained at 18°C. The birds were maintained on a diet (15% CP) based on corn, wheat and soybean meal (SBM) supplied ad libitum between assays.

Prior to the assay, the birds were starved to ensure gut clearance. After fasting for 24 hrs, 33 birds were force fed with 30g of one of the ten jet-sploded CS samples or raw CS (Table III.1), and three birds were starved for 48 hrs longer. The 11 test ingredients were finely ground and stored at -30°C to prevent fatty acid oxidation prior to feeding. The excreta voided by each bird were collected 24 and 48 hrs later after removal of feathers and scales. The excreta energy voided by the birds that were force fed the canola samples (test birds) was corrected for metabolic fecal and endogenous urinary energy losses by subtraction of the excreta energy losses of the birds that were fasted for 72 hrs (fasted controls). The correction involved the random pairing of the test birds with the fasted controls. The assay was repeated 14 days later with birds from the same population to provide six replicates of the TMEn values for each of the ten jet-sploded- and raw CS samples. The allocation of treatments to adult birds was made at random within assays.

TMEn values were calculated using the following equation:

$$\text{TMEn (kcal/gDM)} = \frac{\text{GEi} - [\text{GEex} + 8.22(\text{NBfed})] + [\text{GEm} + 8.22(-\text{NBfast})]}{\text{DMi}}$$

where GEi = gross energy of feed

GEex = gross energy excreted by test birds

NBfed = nitrogen balance of test birds

GEm = gross energy excreted by fasted (control) birds

NBfast = nitrogen balance of fasted birds

DMi = dry matter intake

Growth Assay

Raw Canada Grade 1 full-fat CS and ten samples of jet-sploded seed were each incorporated into isocaloric (3.124 kcal/g) and isonitrogenous (3.55% N) corn-SBM diets at a level of 15%, (Table III.3). All canola samples were ground to pass through a 1mm screen prior to dietary inclusion. In order to grind the full-fat CS effectively, it was first mixed 50:50 by weight with ground corn then put through a hammer mill. This produced a product that could be handled without difficulty. All CS samples used in this trial were ground in a similar manner.

Four replicate groups of ten day-old broiler chicks (Hubbard) were allocated to each of 12 dietary treatments. The birds were housed in electrically heated, thermostatically controlled, battery brooders with wire screen floors. Artificial lighting was continuous. Water and the test diets were supplied ad libitum. All diets were supplemented with 5 kg of granite grit (chick size #1) per 100 kg of diet. Feed consumption and weight gains per cage were recorded on a weekly basis. Any bird that died during the study was sent to a veterinary laboratory (Alberta Agriculture, Animal Health Division, O.S. Longman Bldg., Edmonton, Alberta) for autopsy.

At 21 days of age, three birds from each cage were selected at random and killed by cervical dislocation. Live body weights, gizzard weights and the weight of grit retained within the gizzard were recorded. The gizzard was excised by cutting through the isthmus anterior to it and the pylorus immediately posterior to it. Adherent fatty tissue and the gizzard contents were removed prior to weighing. The gizzard contents were washed into a 50ml beaker and the

mixture agitated under running water to ensure total separation of grit from digesta. Recovered grit was air-dried prior to weighing.

Analytical Methods

Samples of the raw CS were analysed for proximate constituents (Association of Analytical Chemists (AOAC) 1980) and acid detergent fiber (Goering and Van Soest 1970). The individual glucosinolates in the oil-extracted air-dried flour of the ten jet sploded- and the raw CS samples were measured as their trimethylsilyl (TMS) derivaties by gas chromatography using benzyl glucosinolate as the internal standard (Duan and McGregor 1981). Oil was extracted from the seed using the Swedish Tube method (Troeng 1955). Myrosinase activity was determined by gas chromatography of allyl nitrile and allyl isothiocyanate in the oil-extracted air-dried flour with ethyl isothiocyanate as the internal standard (Gijzen and McGregor, unpublished).

The excreta were frozen, freeze-dried, allowed to come to equilibrium with atmospheric moisture, weighed, mixed and ground to pass through a 1mm screen. Samples of the excreta and the test diets were assayed for GE in an adiabatic bomb calorimeter (Model 1241, Parr Instrument Co., Moline, Ill.) and for nitrogen and moisture by the methods descibed by the AOAC (1980). A value of 8.22 kcal/g N was used to correct the GE of the excreta to zero nitrogen balance (Hill and Anderson 1958; Fisher 1982).

Statistical Analysis

Data was analysed statistically using the Statistical Package for the Social Sciences X (SPSSX). The treatment means (n=6) for the TMEn values of the raw (control) and ten jet-sploded canola samples were analysed by single factor analysis of variance. Where appropriate, the treatment means were tested ($P<0.05$) using the Student-Newman-Keuls (SNK) multiple range test when preceeded by a significant F-test (Steel and Torrie 1980).

The treatment means (n=12) for body weight gain, feed consumption, feed efficiency (gain:feed), gizzard weight and gizzard gravel accumulation (by weight) to three weeks were

computed and analysed individually by single factor analysis of variance. Where appropriate, the treatment means were tested ($P<0.05$) using the Student-Newman-Keuls (SNK) multiple range test when preceeded by a significant F-test (Steel and Torrie 1980).

C. RESULTS

The results of the chemical analyses performed on the raw CS and the ten jet-sploded CS samples are presented in Table III.1. Jet-sploding had no effect on the GE value of CS. There was an increase in ether extract (EE) values of the heated samples compared to the untreated control (45.1 vs 40.7%).

Heat treatment had little effect on the glucosinolate content of CS, (butenyl, pentenyl, hydroxy-3-butenyl, and hydroxy-4-pentenyl), (Table III.2). Only at the highest temperature (182°C) was there an apparent decline in glucosinolates. All CS samples were below the required limit of 30 μmoles glucosinolates/g (Certification Mark, 'Canola', Registration No. 243,138, Ottawa, 1980). There was however, a significant and dramatic decrease in myrosinase activity in all of the heat-treated CS samples. Taking the naturally occuring myrosinase activity in the raw CS to be 100%, the application of heat resulted in no more than 0.45% activity in any of the ten jet-sploded samples. It would thus appear that heat treatment in the Jet-Sploder for 22.2 sec at 116°C is sufficient to completely inactivate native myrosinase enzyme in whole CS.

The TMEn values derived from this trial are presented in Table III.4. From these results it appears that heat treatment in the Jet-Sploder has no significant ($P<0.05$) effect on the TMEn of CS, despite the apparent increase in lipid availability. The TMEn value for raw CS (5.14 kcal/g DM) is well within the range of TMEn values obtained by other authors and indicates that the birds experienced no difficulty in assimilating the ground seed samples.

The inclusion of either 15% raw or jet-sploded CS had no significant effect ($P<0.05$) on the feed intake of broiler chicks to three weeks of age (Table III.5). However, there was a slight trend towards somewhat greater feed intakes for chicks fed the basal diet (0% CS). Average body weight gain during the three-week trial was significantly ($P<0.05$) greater for

chicks fed the control diet than for those fed the CS-containing diets. There was no significant difference ($P>0.05$) in body weight gain between birds consuming raw CS and those consuming the jet-sploded product.

D. DISCUSSION

The TMEn values obtained for the raw *Brassica campestris* cv Tobin CS compares quite favorably with the TMEn values reported elsewhere in the literature. Sibbald and Price (1977) reported a range in TMEn for 9 varieties of *B. campestris* of 3.91-5.35 kcal/g DM. In the present study, a TMEn of 5.14 kcal/g DM was obtained for the raw CS, well within the range obtained by Sibbald and Price. However, closer examination of their data revealed that the TMEn estimate observed in the present study was much higher than those reported for the double-zero cultivars CZY3-1813, CZY3-1821 and CZY4-941, (3.91, 4.77 and 4.46 kcal/g DM, respectively). Similarly, for Tobin CS, GE was higher (6.82 vs @ 6.60 kcal/g DM), %CP lower (20.1 vs 24.8%), ether extract lower (40.7 vs 37.0%) and crude fiber higher (14.9 vs @ 11.7%), respectively. Muztar et al. (1978) reported TMEn values of 4.57± 0.34 and 4.65±0.29 kcal/g DM for whole Candle and Tower RS, respectively. The much lower TMEn values reported in this case may have been due to the inability of the test birds to adequately masticate the whole, unground RS used. In the present study, the whole CS was finely ground prior to force feeding to prevent such effects. However, some degree of caution must be exercised when making these comparisons since the cultivars used are from different genetic backgrounds and were grown under different environmental conditions.

The relatively high crude fiber and ADF values obtained reflect the high proportion of hull in relation to embryonic tissue present in CS. Appelqvist and Ohlson (1972) reported that hulls comprise about 16% of seed weight. Bell and Shires (1982) observed that RS hulls contained about 44% crude fiber and 67% ADF, and Vose (1974) suggested that the fiber content of whole RS was virtually all contained in the hull. It has been reported that low fiber fractions seperated from rapeseed meals (RSM) by air classification contained 35% (Seth and Clandinin 1973) to 43% (Bayley and Hill 1975) more ME than the original meals suggesting

that ME values may be impaired by high dietary fiber contents. Stringam et al. (1974) and Bell and Shires (1982) reported that seeds with brown seed coats contain appreciably more fiber than seeds with yellow seed coats. The Tobin cultivar used in this study produces seeds with brown seed coats. Bell (1984) suggested that in view of the nature of the carbohydrate found in CS hulls and the amount of lignin present, it is probable that the digestibility of hull carbohydrates by chickens is low. This high fiber content may impair optimal energy and protein utilization in chickens and may be a contributing factor in the somewhat lower than average TMEn results previously obtained in this laboratory using similar canola cultivars (Shires, pers. comm.).

Heat treatment has been reported to improve the nutritional value of low glucosinolate RS for mice (Josefsson and Munck 1972) but not for laying hens (Leeson et al. 1978). Shires et al. (1981) suggested that some form of heat treatment was necessary for CS prior to incorporation into the diets of broiler chickens. The authors in this later study used autoclaving as the method for heat treating CS. They suggested that the beneficial effect of autoclaving on the utilization of dehulled CS may be related in part to the disruption of cellular structure which would make the oil in the seed more accessible to avian digestive enzymes, in part to the destruction of glucosinolates, and in part to the destruction of myrosinase. Glucosinolates, upon hydrolysis by the enzyme myrosinase, yield toxic isothiocyanates, oxazolidinethiones, nitriles and inorganic thiocyanate ion. It has been demonstrated that the type and proportions of the hydrolytic products of glucosinolates in low glucosinolate RSM vary with heating temperature (Josefsson 1975: Josefsson and Uppström 1976). The autolysis of unheated RSM yielded nitriles whereas the hydrolysis of glucosinolates in heated RSM produced isothiocyanates and oxazolidinethiones, which are less toxic to mice than are nitriles (Josefsson 1975).

Appelqvist and Josefsson (1967) concluded that myrosinase could be effectively destroyed by heat treatment when the seed's moisture content was about 8%. With the Jet-Sploding process, any moisture required to precipitate enzyme inactivation must be present in the seed prior to heat treatment, since the process uses only dry air heated to 316°C. The

whole CS prior to heat treatment had a moisture content of 7%, (93% DM), and this level, based on the observations of Appelqvist and Josefsson, should be sufficient to allow complete inactivation of myrosinase. This was in fact the case as is illustrated in Table III.2. Myrosinase activity was completely destroyed in all heat-treated samples heated from 116°C to 182°C. Heat treatment using the Jet-Sploder, however, had little effect on the total measured glucosinolates (μmoles/g DM), in all but the highest temperature treatment, (17.503 μmoles/g oil free DM at 182°C). Shires et al. (1981) reported a loss in 3-butenyl and 4-pentenyl glucosinolates, and a reduction in 2-hydroxy-3-butenyl and total glucosinolates with autoclaving, results somewhat contrary to those obtained in the present study using jet-sploding.

Heat treatment had no significant ($P<0.05$) effect on the TMEn values of CS heated at different temperatures. In addition, the TMEn values of heat-treated CS did not differ significantly from that obtained with raw CS (Table III.4), despite the theoretical advantages proposed due to the destruction of myrosinase by heat and the concomitant release of oil from the cellular structure of the endosperm. It would thus appear that these beneficial effects are being limited by other factors preventing the birds from achieving maximal response. On the basis of results reported previously using full-fat RS and CS, it is probable that maximal utilization of energy and protein is being impaired by the presence of a high fiber content in the ground seed meal. Since the dominant carbohydrates in CS hulls are cellulose and pentosans, it is probable that the digestibility of hull carbohydrates would be low, especially in view of the amount of lignin (12-24%) usually present (Bell 1984).

There was no reduction in feed intake over the three week growth trial with the incorporation of 15% jet-sploded CS compared to either the control (0% CS) diet or diets containing 15% untreated CS. Mean feed intake for birds fed the control diet (729g), was slightly higher than that of birds fed any of the diets containing either raw or heat-treated CS. For the diet in which raw, untreated CS was incorporated, mean feed intake was 644g/bird. Average weight gain to three weeks was significantly ($P<0.05$) greater for the corn-SBM controls (0% CS) than for any of the CS-fed birds. Feed conversion however, was

highest for birds fed the diet containing raw, untreated CS. There was however, no difference in feed conversion values between birds fed the corn-soybean meal control diets and those fed jet-sploded CS.

Summers et al. (1982) reported that CS fed to broilers at dietary levels of 17.5% or higher resulted in reduced weight gains and feed intake,in comparison to birds fed a control (0%CS) diet, but feed:gain ratios to 7 wks were similar. They observed a marked improvement in feed:gain from 4 to 7 wks with increased CS inclusion in the diet. The corn-SBM controls had feed:gain values of 1.62 whereas the CS-fed birds had feed:gain ratios of 1.61. These results are in disagreement with results observed in the present study. Summers et al. (1983) however, did not grind the whole CS before steam-pelleting and this may have resulted in the higher feed intakes due to an inability of the chicks to adequately digest whole CS. With grinding and heat treatment, (by the method of Woodly et al. (1972)), at 250°C for 2 min, average weight gain and feed:gain were improved. Summers et al. (1982) suggested that the poor growth rate of the chicks fed diets containing CS may have been due to depressed feed intake or to an apparently low fat retention.

Robblee et al. (1983) conducted a growth trial in which raw flaked CS was incorporated into isocaloric, isonitrogenous diets and fed at increasing (0,10 15, 20%) levels to broilers during the starting and finishing periods. In a second trial, raw flaked CS was included in the rations at either 0 or 10% and fed as mash or crumbles. From the first trial, they concluded that CS could be included in broiler diets at up to 10% to provide good growth rate, feed conversion and 'normal' mortality. However, when the level of CS was increased to 15 or 20% there was a successive decrease in growth rate, but mortality and feed conversion were not affected.

Leeson et al. (1978) using diets containing 10 or 20% Tower RS fed either as raw whole seed, dry-heated whole seed or autoclaved whole seed found that body weight gain to four weeks of age was not significantly influenced by dietary treatment, although birds eating 20% dry-heated RS had a significantly ($P<0.05$) inferior feed intake:body weight gain in comparison to that calculated for the corn-soya control birds (1.76 vs 1.66 respectively).

Body weight gain to three weeks in the present study was depressed by the addition of either 15% untreated CS or 15% jet-sploded CS to the basal diet, compared to the corn-SBM control diet. The reason for this response is not clear although it may be related to the relatively high crude fiber and ADF levels observed in the brown-coated Tobin CS. Mitaru et al. (1983) however found that the inclusion of up to 20% Tower CS hulls in the diets of broilers to three weeks of age had no effect on growth rate, feed efficiency, protein digestibility or ME values, a result somewhat contrary to that of Leslie et al. (1973) who reported that the removal of hulls from RS improved protein and energy digestibilities of the meal for rats.

Bayley and Hill (1975) evaluating the nutritional quality of low and high fiber fractions of RSM for broiler chickens suggested that the poor response exhibited by chicks fed diets containing RSM may have been due in part to the physical texture of the feed. From observation of the birds in that study, it appeared that they needed the first week to become accustomed to the dry powdery diets, but dietary consumption and growth rate improved dramatically by the second week. In the present study the raw untreated CS and the rolled, jet-sploded CS samples were first mixed 50:50 with ground corn and then ground to pass through a 1mm screen prior to dietary incorporation. This additional process resulted in a somewhat dry, powdery diet which may have contributed to the lower growth rates observed. The corn-SBM control diet was not passed through the hammer mill as this treatment was only deemed necessary for diets containing CS. This problem may have been avoided if the diets were pelleted and fed as crumbles after mixing.

Despite the beneficial effect of eliminating myrosinase enzyme, jet-sploding had no apparent effect on improving the nutritional value of full-fat CS for broiler chicks in the starting period. It did yield an improvement in EE values over that for untreated CS, but this did not manifest itself in an improved average body weight gain. Feed conversions were significantly improved ($P<0.05$) compared to the estimates for diets containing untreated CS and were not significantly different from the feed:gain ratios of birds fed the corn-SBM control diets. Woodly et al. (1972) reported that the nutritive value of full-fat RS, when subjected to heating temperatures ranging from 232 to 427°C, was markedly improved. They

suggested that while RS diets were not initially palatable to chicks, when fed over a four week period, the birds overcame the slow start and were as heavy as those fed a SBM control diet at the conclusion of the experiment. Poor initial acceptance may have been due to the presence of sinapine or high levels of erucic (C22:1) acid in the seed. Clement and Renner (1977) demonstrated that high erucic acid RS oils resulted in marked depressions in growth and poorer utilization of dietary energy while the newer low erucic acid varieties resulted in no such depressions. This observation would therefore eliminate erucic acid as a contributing factor to poorer performance observed with Tobin CS, a double zero cultivar containing less than 5% erucic acid in the oil. Srivastava and Hill (1976) reported that heat treatment (dipping seeds in boiling water) of two double zero cultivars of *Brassica napus*, (1788 and 940), resulted in improved weight gains and lower thyroid weights in rats which received these meals as their only source of protein. The reasons for these improvements were not clearly elucidated, but did not appear to be related to the low levels of glucosinolates present in the meals, to the destruction of trypsin inhibitors in the meals or to an increase in the digestibility of their protein.

In an attempt to explain the poorer performance and lower fat digestibility often encountered when CS diets are fed to birds, Shen et al. (1983) formulated corn-SBM diets containing 20% CS or an equivalent amount of added fat (8%) from corn oil, tallow or an animal-vegetable blend fat. They noted no detrimental effects attributable to the inclusion of CS. However, they did note a marked improvement in performance, especially in the digestibility of the fat from CS diets, in response to steam pelleting. When these diets were fed as mash or steam crumbles, marked improvements were noted in the performance of birds fed the crumbled versus mash diets. In the present study, refined corn oil was included not only to boost the energy content of the diets, but also to reduce dustiness. Shen et al. (1983) concluded that much of the variability in results observed when CS-supplemented diets were fed to birds could be related to fineness of grind of the material. The steam pelleting process, in addition to reducing myrosinase because of the application of moist heat, results in sufficient pulverization or breaking up of the seed, to allow for optimum performance with

diets containing up to 20% CS (Shen et al. 1983).

At the end of the trial 144 birds were sacrificed to see whether grit ingestion was influenced by dietary treatment. There appeared to be no correlation between ingested grit and dietary treatment. As the body weight of the chick increased gizzard grit accumulation decreased. It would appear that grit ingestion (and gizzard accumulation), in a well-ground diet is very much an individual bird preference and has no significant effect on overall body weight gain or feed:gain ratios. This trial confirmed the hypothesis that mixing CS with ground corn in a 50:50 ratio prior to grinding in a hammer mill is an adequate treatment for CS prior to incorporationinto diets intended for broiler chickens.

E. SUMMARY

Jet sploding resulted in slightly higher ether extract values in the CS samples and myrosinase activity was effectively eliminated. There was however no improvement in the TMEn values of jet-sploded CS as compared to the raw seed. Weight gains for broiler chicks to 3 weeks of age were not increased by heat treatment although feed:gain values were significantly ($P<0.05$) improved by jet-sploding and were equivalent to that obtained from the corn-soybean meal control diet. Based on these results, a temperature of 116°C in the Jet-Sploder resulted in effective elimination of myrosinase and maximal oil liberation, due to the disruption of cellular structure.

Table III.1. Chemical analysis of test ingredients expressed on a dry matter basis.

Jet-Sploding Temperature	Gross Energy	Crude Protein	Ether Extract	Crude Fiber	ADF	Ash
(℃)	Kcal/g			(%)		
Raw CS	6.82	20.1	40.7	14.9	20.5	4.2
116	6.86	18.8	44.8	-	-	-
121	6.90	19.5	46.3	-	-	-
127	6.87	19.6	45.5	-	-	-
132	6.85	19.4	44.5	-	-	-
138	6.85	19.5	46.3	-	-	-
149	6.86	19.8	45.9	-	-	-
154	6.88	19.9	45.4	-	-	-
160	6.89	19.9	43.1	-	-	-
171	6.89	19.8	44.3	-	-	-
182	6.89	19.8	44.9	-	-	-

ADF, Acid detergent fiber.

Table III.2. Glucosinolate content and Myrosinase activity in test ingredients.

Jet-Sploding Temperature	Glucosinolate					Myrosinase Activity
	3-Butenyl	4-Pentenyl	2 Hydroxy-3-butenyl	2 Hydroxy-4-pentenyl	Total	
(°C)	----------	----------	(μmol/g oil free DM)	----------	----------	(%)
Raw CS	7.157	4.007	11.252	1.317	23.733	100.00
116	6.782	4.285	11.114	1.333	23.514	0.00
121	8.080	4.468	12.245	1.447	26.240	0.50
127	6.787	3.904	12.245	1.379	24.315	0.00
132	7.132	4.151	11.712	1.366	24.361	0.00
138	7.509	4.192	12.635	1.377	25.713	0.50
149	6.988	3.998	11.888	1.354	24.228	0.00
154	6.672	4.168	11.056	1.367	23.263	0.45
160	7.025	3.858	11.372	1.304	23.559	0.25
171	6.772	3.906	10,934	1.331	22.943	0.00
182	5.435	3.202	7.929	0.937	17.503	0.15

Table III.3. Composition of basal diet and canola seed - supplemented diets.

Ingredient	Basal	CS Supplemented
	(%)	
Corn	54.45	50.00
Canola seed (21.5% protein)	-	15.00
Soybean meal (47% protein)	37.00	31.00
Corn oil, refined[1]	4.50	
Calcium phosphate (21% P)	1.70	1.70
Limestone	1.50	1.50
Salt, iodized	0.30	0.30
DL-methionine	0.25	0.20
Vitamin mix[2]	0.20	0.20
Mineral mix[3]	0.10	0.10
Calculated analysis		
Protein (%)	22.2	22.2
Energy (kcal/g)	3.124	3.123
Methionine (%)	0.62	0.60
Lysine (%)	1.27	1.27

[1]Mazola, Canada Starch Co. Ltd., Toronto, Ontario.
[2]Vitamin mix provided per kg of diet: 12,000 IU vitamin ., 1,000 ICU vitamin D_3; 10 IU vitamin E; 2 mg menadione; 5 mg riboflavin; 10 mg d-calcium patothenate; 25 mg niacin; 750 mg choline chloride; 1 mg folic acid; 10 μg vitamin B_{12}; 3 mg pyridoxine hydrochloride; 200 μg d-biotin; 2 mg thiamin hydrochloride; 125 mg ethoxyquin.
[3]Mineral mix provided per kg of diet: 60 mg manganese ($MnSO_4.4H_2O$); 50 mg zinc (ZNO); 0.40 mg iodine (KIO_3); 0.1 mg Selenium (Na_2SeO_3); 5 mg copper ($CuSO_4.5H_2O$); 30 mg iron ($FeSO_4.7H_2O$).

Table III.4. Influence of Jet-sploding temperature on the true metabolizable energy (TMEn) value of canola seed.

Jet-Sploding Temperature	Retention Time	TMEn[1]
(°C)	(sec)	(Kcal/g DM)
Raw CS	-	5.14a
116	22.2	5.24a
121	26.2	5.25a
127	28.4	5.27a
132	30.0	5.12a
138	35.1	5.25a
149	36.1	5.11a
154	38.9	5.09a
160	41.9	5.05a
171	49.7	4.98a
182	51.0	5.12a
SEM[2]		0.08

[1]N-correction factor 8.22.
[2]SEM, standard error of a treatment mean of six replicates.
a Column values with the same letter are not significantly different as determined by the Student-Newman-Keuls test ($P<0.05$).

Table III.5. Influence of Jet-sploding canola seed on feed intake, weight gain and feed conversion of 3 week old broiler chicks.

Jet-Sploding Temperature	Dietary level of canola seed	Feed Intake	Av. weight Gain	Feed Conversion
(°C)	(%)	(g)	(g)	(g feed/g gain)
Control diet	0	729a	511a	1.43a
Raw CS	15	644a	417b	1.55b
116	15	694a	466b	1.49a
121	15	653a	440b	1.48a
127	15	704a	472b	1.49a
132	15	662a	448b	1.48a
138	15	691a	470b	1.47a
149	15	674a	452b	1.49a
154	15	674a	462b	1.46a
160	15	664a	448b	1.48a
171	15	658a	447b	1.48a
182	15	681a	463b	1.47a
SEM[1]		17	13	0.02

[1]SEM, Standard error of a treatment mean of four replicates.
a,b Column values with the same letter or no letters are not significantly different as determined by the Student-Newman-Keuls test ($P<0.05$).

Table III.6. Effect of dietary treatment on body weight, gizzard weight and gizzard gravel content of sacrificed 3 week old broiler chicks.

Jet-Sploding Temperature	Body Weight	Gizzard Weight	Gizzard Gravel Content
(°C)	(g)	(g)	(g)
Control diet	592a	12.3a	0.98a
Raw CS	505a	12.0a	1.49a
116	565a	12.9a	1.79a
121	535a	12.2a	1.00a
127	539a	13.3a	1.49a
132	543a	11.5a	1.92a
138	533a	12.6a	1.37a
149	521a	12.4a	1.41a
154	522a	12.2a	2.28a
160	530a	12.8a	0.84a
171	510a	11.0a	1.32a
182	568a	12.1a	1.58a
SEM[1]	23	0.5	0.35

SEM, standard error of treatment mean of twelve replicates.
a Column values with the same letter are not significantly different as determined by the Student-Newman-Keuls test ($P<0.05$).

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IV. Evaluation of Jet-Sploding on the Apparent and True Metabolizable Energy Values of Full-Fat Canola Seed for Chickens.

A. INTRODUCTION

It is generally accepted that metabolizable energy (ME) values provide a reliable estimate of the available energy content of feedstuffs, (De Groote 1974, Miller 1974). Apparent metabolizable energy (AME) is the difference between the gross energy (GE) in the food consumed and the GE in the feces and urine (National Research Council 1981):

$$AME = GE \text{ in food} - GE \text{ in excreta}$$

The term 'apparent' is used because the excreta of an animal contains energy which is not derived from the food, namely the metabolic fecal energy (FmE) and the endogenous urinary energy (UeE). The measurement of true metabolizable energy (TME) involves the correction of the GE of the excreta for FmE and UeE losses:

$$TME = GE \text{ in food} - [GE \text{ in excreta} - (FmE + UeE)]$$

Part of the ME is retained in the body as protein which may be degraded and excreted in the form of uric acid. The correction of ME values (AMEn and TMEn) for nitrogen gained or lost from the body during the assay eliminates the variation in nitrogen retention associated with the age of the assay bird and the level of dietary protein. The correction for nitrogen retention is made on the assumption that the oxidation of tissue protein will yield uric acid only, which has a GE/g of N of 8.22 kcal (Miller 1974).

The determination of ME by the conventional total collection technique is laborious, expensive and tends to be impractical for the routine assay of individual samples of feedstuffs

and diets. Determination of AMEn by this method involves the measurement of total food intake and the total excreta output for a period of 3-5 days. The total collection technique involves an assumption that excreta voided during a period of time corresponds to feed ingested during the same period. One of the major objections to the total collection technique is that feed consumption and excreta output are difficult to measure accurately (Sibbald 1982).

The use of indicators obviates the need to measure either feed intake or excreta output and avoids some of the problems related to fluctuating moisture levels in the feed. The most common indicator used in AME studies is chromic oxide (Cr_2O_3). Other indicators used in bioavailable energy (BE) assays with poultry include crude fiber (Almquist and Halloran 1971), polyethylene (Roudybush et al. 1974) and acid insoluable ash (Vogtmann et al. 1975). Indicators are attractive because they permit the derivation of acceptable BE values even when feed is spilled and some excreta are not recovered.

The rare earth elements are becoming increasingly popular as markers in ruminant (Gray and Vogt 1974) and monogastric studies (Kennelly et al. 1980). Among the elements that have been studied are cerium (Ce) (Huston and Ellis 1968) and dysprosium (Dy) (Young et al. 1975; Kennelly et al. 1980). These elements are not absorbed from the gastrointestinal tract and possess many of the properties of ideal nutritional markers (Ellis 1968). Radioactive isotopes of these elements have been used but result in animal contamination and problems associated with the disposal of radioactive waste. The use of instrumental neutron activation analysis (INAA) circumvents both of these difficulties.

The bioassay for TMEn was developed by Sibbald (1976) and is simpler, faster and cheaper to conduct than the conventional total collection technique for AMEn. It involves the force feeding of adult roosters with 30g of the test ingredient and the total collection of excreta for 24 hrs. Recent modifications of the method (Sibbald 1983) include the extension of the period of excreta collection from 24 to 48 hrs and the correction of the values to zero nitrogen balance (TMEn). These changes in methodology have improved the precision of the assay but render the values obtained by the original method obsolete.

Muztar et al. (1980) reported TMEn values for whole Candle and Tower canola seed (CS) of 4.25-4.57 and 4.65-5.43 kcal/g respectively. They also reported AMEn values of 4.43 and 4.31 kcal/g for ground full-fat Tower and Candle CS. Sibbald and Price (1977) obtained TME ranges of 3.91-5.35 kcal/gDM for nine varieties of *Brassica campestris* and 4.59-5.71 kcal/gDM for ten varieties of *B. napus*.

The objectives of this study were thus:

1. To calculate estimates of the TMEn and AMEn of full-fat CS (*B. campestris* cv. Tobin) for chickens in order to establish representative ME values which can then be applied to dietary formulation.
2. To evaluate the effect of heat treatment on the ME content of CS using the Jet Sploder^{TM} process and
3. To compare ME values obtained using the total collection technique with the dysprosium chloride indicator technique and thus evaluate the reliability of these methods of assay by ranking them against values obtained using the TMEn assay.

B. MATERIALS AND METHODS

Assay for TMEn

Eighteen adult male egg type (Shaver Starcross 288) chickens were used to measure the TMEn values of the test ingredients by the method of Sibbald (1976, 1983). The birds were housed singly in alternate cages, providing a floor area of 1151 cm²/bird, to minimize the cross contamination of excreta. Water was provided ad libitum via water cups. Fecal samples for individual birds were collected in trays placed under the cages. Artificial lighting of the room was controlled automatically to provide 14 hrs of light and 10 hrs of darkness. Room temperature was maintained at 18°C. The birds were fed a corn, wheat, and soybean meal diet supplied ad libitum between assays.

Prior to the assay, the birds were starved for 24 hrs to ensure gut clearance. After fasting, 16 birds were force fed with 30g of either raw or Jet-sploded Canada grade 1 CS, and

2 birds were starved for 48 hrs longer. All feed samples were finely ground and stored at -30 °C prior to feeding to prevent fatty acid oxidation. The excreta voided by each bird were collected quantitatively 24 and 48 hrs later after removal of feathers and scales. The excreta energy voided by the birds that were fed the canola samples (test birds), was corrected for FmE and UeE losses by subtraction of the excreta energy losses of the birds that were fasted for 72 hrs (fasted controls). The correction involved the random pairing of the test birds with the control birds. The assay provided 8 replicates of the TMEn value of the raw and jet-sploded CS samples. The allocation of treatments to adult chickens was made at random within assays.

True metabolizable energies were calculated using the following equation:

$$\text{TMEn (kcal/gDM)} = \frac{\text{GEi} - [\text{GEex} + 8.22(\text{NBfed})] + \text{GEm} + 8.22(-\text{NBfast})]}{\text{DMi}}$$

where: GEi = gross energy of feed

GEex = gross energy excreted by test birds

NBfed = nitrogen balance of test birds

GEm = gross energy excreted by fasted controls

NBfast = nitrogen balance of fasted birds

DMi = dry matter intake

Assay for AMEn - Total Collection Method

Diets

Each of the samples of either raw or jet-sploded CS was incorporated in partial replacement of the basal diet (Table IV.1) at levels of 5, 10, 15 or 20% DM. The CS samples were ground prior to dietary inclusion by mixing them 50:50 by weight with ground corn and ground to pass through a 1mm screen. The mineral and vitamin

supplements constituted an equal portion of the basal and test diets and were assumed to not contribute to the AMEn (Sibbald and Slinger 1963). A correction was made in the calculation of dietary AMEn values to adjust for the inclusion of these supplements.

Adult Assay

36 adult male egg type (Shaver Starcross 288) chickens were housed singly in alternate cages to minimize cross-contamination of excreta. Water was provided ad libitum via water cups. Fecal samples from individual birds were collected in trays placed under the wire screen floors of the cages. Artificial lighting of the room was controlled automatically to provide 14 hrs of light and 10 hrs of darkness. Room temperature was maintained at 18 °C. The eight test diets (two test ingredients x four levels of inclusion) and the basal diet were assigned at random to 32 and four cages respectively.

Birds were fed the experimental diets for 10 days prior to the measurement of total feed intake and total excreta voided for a period of four days. At 0800 hours on day 10 the feed was removed and the birds starved to facilitate gut clearance. After starving for 24 hrs, the birds were returned to their experimental diets. Fecal samples were collected quantitatively at 24 hr intervals, after separation of spilled feed, feathers and scales. The weight of spilled feed was recorded daily. The birds were fed from plastic one gallon ice cream containers with a 15cm diameter hole cut into the lids to minimize feed spillage. At 0800 hrs on day 14 the feed was removed and the birds starved for 24 hrs. The collection trays were removed at 0800 hrs on day 15 and the excreta collected quantitatively. Samples of the diets were taken at the start and the end of the collection period for standard dry matter analysis.

Chick Assay

The AMEn assay was repeated using male chicks of meat type (Hubbard) birds. The birds were reared from 1-16 days of age in electrically heated, thermostatically controlled battery brooders with wire screen floors. Artificial lighting of the room was continuous. Water and the basal diet supplemented with minerals and vitamins were

supplied ad libitum. On day 14 the birds were wing-banded and weighed individually. The lightest and the heaviest birds were discarded and the remaining birds were assigned to 36 metabolism cages, each containing three birds, providing 384 cm ^{2} of floor space per bird. The allocation of birds to cages was made on the basis of body weight to equalize both mean body weight and body weight distributed among the cages. The eight test diets (two test ingedients x four levels of inclusion) and the basal diet were assigned at random to 32 and four cages respectively.

Birds were fed the experimental diets for 10 days prior to the measurement of total feed intake and total excreta voided for a period of 4 days. At 1600 hrs on day 25, the feed was removed and the birds were starved to empty their digestive tracts. After fasting for 16 hrs, the birds were returned to their experimental diets and excreta trays placed under the wire screen floors of the cages. Excreta was collected quantitatively as in the previous assay. Feeding troughs were covered by a hood to minimize spillage. At 1600 hrs on day 29 the feed was removed and the birds starved to empty their digestive tracts. After fasting for 16 hrs, the trays were removed at 0800 hrs on day 30 as descibed previously.

AMEn values were calculated using the following equation:

$$\text{AMEn (kcal/gDM)} = \frac{(GEi - GEex - 8.22(NBfed)) \times 1.037}{DMi}$$

where: GEi = gross energy of feed

GEex = gross energy excreted by test birds

NBfed = nitrogen balance of test birds

DMi = dry matter intake

1.037 = correction factor for the inclusion of the vitamin/mineral premixes

Assay for AMEn - Dysprosium chloride indicator Method

Dysprosium chloride ($DyCl_3.6H_2O$) was incorporated into the above diets at a concentration of 15ppm elemental Dy. It was initially added to 1kg of the vitamin premix ground to a similar fineness. The vitamin-dysprosium chloride premix was then added gradually to the test and basal diets at a level of 0.20% until complete mixing was achieved.

Two 3.0g samples from each of the 9 diets and one 2.0g fecal sample from each pen were accurately weighed into acid-cleaned 1.5 cm^3 polyethylene vials and irradiated in the SLOWPOKE reactor following the standard INAA scheme outlined in Kennelly et al. (1980).

AMEn values from this method were calculated using the following equation:

$$\text{AMEn (kcal/gDM)} = \text{GEi} - \text{GEex} \times \frac{\text{Dy/g feed}}{\text{Dy/g feces}} - 8.22\ \text{NB} \times \frac{\text{Dy/g feed}}{\text{Dy/g feces}}$$

where: GEi = gross energy of feed

GEex = gross energy excreted by test birds

NB = nitrogen balance

The amount of Dy present in the sample in terms of counts/g (C') was corrected for the dead time (DT) when the electronics are actively processing events not included in the preset 60s live time (LT). The corrected counts/g of sample is given as:

$$\text{C (counts/g sample)} = \text{C'}[1 + (\%\text{DT} \times 0.0025)]$$

Assay for Apparent Lipid Digestibility

The assay for apparent lipid digestibility (ALD) was undertaken in an attempt to explain the lower AMEn values obtained from the chick bioassays. The determination of total lipids in both the feed and the fecal samples used in this assay is a modification of the method of Braddock et al. (1968).

Two gram samples of either finely ground feed or feces were placed in 50ml screw cap culture tubes with teflon-lined caps and refluxed in 6ml 1N alcoholic KOH for 30 min. 5ml of water and 20ml of petroleum ether were then added and the mixture agitated for 1 min. The immiscible organic phase was then discarded after complete separation to remove the non-saponafiable lipids. A 15ml quantity of petroleum ether was added and the mixture agitated for 30 sec prior to centrifugation at 3-4°C, (Beckman model J-6B/P, Beckman Inst. Div., Irvine, Ca.) for 90 sec with a relative centrifugal force (RCF) of 750 x g. The petroleum ether phase was again discarded.

The mixture was then acidified by adding 5ml 25% HCl and 20ml petroleum ether, shaken for 1 min, and allowed to separate well (15-20 min), prior to removal of the organic phase into pre-weighed 20ml scintillation vials. The extraction was repeated with a second 20ml aliquot of petroleum ether and centrifuged for 3-4 min, (RCF=750 x g). This second extraction was then added to the first extraction in the pre-weighed vial and the petroleum ether evapourated off on a hot plate at 70°C. The fatty acid residues were then weighed and expressed as a percentage. ALD was calculated in the usual manner.

Analytical Methods

The excreta were frozen, freeze-dried, allowed to come to equilibrium with atmospheric moisture, weighed, mixed and ground to pass through a 1mm screen. Samples of the excreta and test samples were assayed for gross energy in an adiabatic bomb calorimeter (Model 1241, Parr Instrument Co., Moline, Ill.) and for nitrogen and moisture by the methods described by the AOAC (1980). A value of 8.22 kcal/g N was used to correct the gross energy of the excreta to zero nitrogen balance (Hill and Anderson 1958; Fisher 1982).

Statistical Analysis

Data were analysed statistically using the Statistical Package for the Social Sciences X (SPSSX). The treatment means (n=8) for the TMEn values of the raw CS and the 'optimally' heated (jet-sploded) CS, corrected to zero nitrogen balance, were analysed using a

2-tailed t-test (Steel and Torrie 1980). The AMEn values of the raw CS and the 'optimally' jet-sploded CS, corrected to zero nitrogen balance, were estimated by standard regression analysis. The values were separated according to dietary treatment (raw vs. jet-sploded) and age (chick vs. adult) of test birds. The treatment means (n=4) for the lipid digestibility values were analysed using a standard 2-way anova with age and dietary treatment as the main effects (Steel and Torrie 1980).

C. RESULTS

The values obtained for the TMEn of the raw CS and canola seed jet-sploded at 116°C were not significantly different (t=-0.09 with 14df and a 2-tailed probability of P=0.929). Birds fed the raw CS yielded a TMEn of 5.04 kcal/g DM whereas those fed the jet-sploded product yielded a TMEn of 5.05 kcal/g DM. It would thus appear that the TMEn, used as an estimate of the BE, is not influenced by this form of heat treatment despite a somewhat improved ether extract value obtained under the same conditions in the previous trial, (40.7 vs. 44.8% for the raw untreated CS and 116°C jet-sploded CS respectively).

The estimate of AMEn obtained using the usual technique of total collection are presented in Table IV.2. In both cases (raw CS vs. jet-sploded CS) the adult birds yielded somewhat higher values compared to those obtained using chicks (4.26 vs. 3.80 kcal/g DM) and (5.06 vs. 4.39 kcal/g DM) respectively.

The AMEn estimates obtained using the dysprosium chloride ratio analysis (Table IV.4) tended to yield results that were more variable than those obtained with the total collection method. The AMEn estimates for the jet-sploded CS tended to be slightly higher in the chick trial (4.51 vs 4.39 kcal/gDM) but somewhat lower in the adult trial (4.95 vs 5.06 kcal/gDM). With the raw CS, results using this method of analysis were much lower for both chicks and adults (3.36 vs 3.80 kcal/gDM) and (3.47 vs 4.26 kcal/gDM) for the total collection and dysprosium marker analysis respectively.

The percent recoveries of elemental Dy are presented in Table IV.3. Chicks produced consistently higher and more uniform (±1.4%) recoveries than did adult birds, indicating that

the 16-hour post collection fast was sufficent to recover 94.3% of the administered Dy. Adult birds produced more variable results (±3.6%) and a lower average percent recovery (86.5%), suggesting in this case that the 24-hour post collection fast was insufficient time in which to facilitate quantitative Dy recovery. For the chick trial, the recoveries were not significantly different ($P<0.05$) from those achieved for the control diet. Results were somewhat lower with diets containing raw CS, but no consistent trends were apparent. Dy recoveries in the adult trial did not differ significantly ($P<0.05$) between dietary treatments and individual recoveries varied quite substantially between individual birds irrespective of diet (55.9 - 100.0%), suggesting that there may have been variable amounts of crop-fill in individual birds prior to the post-collection fast. This observation coupled with an insufficient fast period may have been contributing factors towards incomplete gut clearance prior to final fecal collection with a concomitant decrease in apparent Dy recovery.

There was no noticeable change in the ALD estimates with increased levels of inclusion of either 15% raw CS or 15% jet-sploded CS for either adults or chicks. Adult birds did have a 13.2% improvement in ALD (79.5 vs. 69.1%) over chicks ($P<0.001$). In addition, birds in both age groups had improved lipid digestibilities on diets containing jet-sploded CS compared to those containing raw CS (77.1 vs. 71.5% respectively) ($P<0.001$). It would thus appear that while there is not a trend for the ALD to either increase or decrease with increasing levels of CS in the diet, digestibility does improve with age and with heat treatment.

D. DISCUSSION

Based on the results of the previous experiment, another batch of *Brassica campestris* cv Tobin was jet-sploded at 116°C (retention time @22.2 sec). The TMEn value obtained for this batch although lower than that obtained in the previous trial (5.05 vs 5.24 kcal/gDM), were not significantly ($t=-0.09$ with 14 df) different from the value obtained for untreated CS (5.05 vs 5.04 kcal/gDM). The TMEn obtained herein is still in keeping with the range of TMEn values presented by Sibbald and Price (1977) for *B. campestris* cultivars (3.91 - 5.35

kcal/gDM). Although this value is lower than that reported in the previous trial using the same batch of raw CS, it is still somewhat higher than those reported by Sibbald and Price (1977) for the 3 double-zero cultivars CZY3-1813, CZY3-1821 and CZY4-941, (3.91, 4.77 and 4.46 kcal/gDM respectively). The value obtained for raw full-fat Tobin CS is more in keeping with that determined by Muztar et al. (1980). They obtained values of 5.36±0.12 and 5.09±0.11 kcal/gDM for full-fat Candle and Tower CS, respectively.

There is a growing body of evidence to suggest that data for the TME system are of high quality inasmuch as they are reproducible among laboratories (Kessler and Thomas 1978; Mollah et al. 1983) and repeatable within laboratories (Dale and Fuller 1981), are additive (Dale and Fuller 1980; Sibbald 1977), and tend to be independent of the assay bird (Dale and Fuller 1980; Ostrowski-Meissner 1984; Sibbald 1976). The reason for the apparent discrepancy observed in the present study is thus all the more perplexing. Muztar et al. (1981) suggested that a possible factor contributing to the observed differences in the TMEn values between the two trials is the manner in which the correction for FmE + UeE losses are derived. In this and the previous trial the author used the means of groups of 8 and 6 birds randomly selected from the population upon which to base the FmE + UeE correction value. Muztar and Slinger (1980a) have reasoned that with the adoption of such a procedure one might choose a group of birds, the majority of which fall into the highest or lowest FmE + UeE excretion range of a given population. This could easily introduce a significant difference in the TMEn value in assays conducted at different times. Differential rates of passage of digesta between populations has also been suggested to affect TMEn values (Muztar and Slinger 1980b). Shires et al. (1979) suggested that body weight and the protein content of previous diet (the maintenance diet fed between assays) can influence FmE + UeE losses. However, in the present studies, the same maintenance diet was fed to the population between assays, which should have not have resulted in widely varying CP contents. The fact that there were differences in the TMEn of both the raw and jet-sploded CS precludes the supposition that differences in the TMEn could be attributed to inaccuracies in the measured retention times (and subsequently higher jet-sploding temperatures) for subsequent batches of heat-treated

CS.

The assay of Sibbald (1976a,b; 1983) for TMEn assumes that the excreta voided by the fasted controls provides a valid estimate of the FmE and UeE losses of the test birds. This assumption may be erroneous because of the (bird's) need to utilize body fat and protein for maintenance of vital body functions during the fast. The catabolism of body protein yields amino nitrogen which is excreted via the urine primarily in the form of uric acid, a product with a high GE content (8.22 kcal/gDM). It is possible that the force feeding of control birds with a mixture of corn, starch, glucose and corn oil may spare the catabolism of body protein for gluconeogenesis and minimize the excretion of nitrogen in the urine (A. Shires, pers. comm.). McNab and Fisher (1981) reported that the force feeding of roosters with 25g glucose reduced the endogenous energy losses by 48%. In a subsequent experiment, the force feeding of glucose at levels ranging from 0-40g had no consistent effect on the endogenous losses of energy or nitrogen (Fisher 1982). Since the administration of glucose failed to provide a more precise or accurate estimate of the endogenous losses of energy or nitrogen, its provision can be judged on the ethics of fasting birds for up to 96 hrs and not by statistics. The estimation of endogenous energy losses by force feeding a test feed at variable levels greater than zero and then extrapolating to zero intake the line relating energy excretion to energy intake, may be considered more humane because it eliminates the need for fasted controls (Shires, unpublished).

That AMEn values often vary with voluntary feed intake whereas TMEn values do not is well established (Sibbald 1975). Misleading AMEn values may often result if the test material is unpalatable, because voluntary consumption of the assay diet is reduced. This has often been the case with the older high glucosinolate-high erucic acid rapeseed cultivars, and because of this, test birds are often introduced to the test diets 10 days prior to the collection period. In the present study, there was a much closer agreement between the AMEn and TMEn estimates for jet-sploded product (5.06 vs 5.05 kcal/gDM) than that obtained for untreated CS (4.26 vs 5.04 kcal/gDM), respectively. The reason for this trend was not at once apparent but may stem in part from the presence of an unpalatable factor in unprocessed CS

when fed at high levels (20% CS inclusion) or from the disruption of cellular structure in the jet-sploded seed which would make the oil more accessible to digestive enzymes, thus increasing the apparent lipid digestibility and hence the resultant increase in AMEn. The presence of glucosinolates and active myrosinase in the untreated CS may also contribute to decreased voluntary intake leading to a lower AMEn value.

The AMEn values obtained from the chick bioassay tended to be much lower than that obtained from the adult trial for both the heated and untreated CS (13.3 and 10.8% lower respectively). Woodly et al. (1972) had indicated that while diets containing rapeseed were not initially palatable to chicks, when fed over a 4 week period, birds overcame the slow start and were as heavy as those fed a soybean control diet. In the present trial, chicks were reared to 16 days of age on the basal diet (Table IV.1) before being transfered to the test diets (0, 5, 10, 15, 20% CS) for 10 days prior to measured feed intake and fecal output. It is probable that, in the case of chicks, the 10 day adaptation period (to the test diets) is not long enough when CS is to be analysed, and as a result, depressed feed intake may continue into the test period, resulting in low AMEn values.

The malabsorption of fat caused by the feeding of raw untreated soybean protein in the chick has long been appreciated (Nesheim et al. 1962). The effect can be marked, a 20% inclusion of raw soybean meal inducing a decrease in fat absorbtion from 95% to 40% or less (Garlich and Nesheim 1965). The suggestion has been proposed that raw soybean possesses a heat-labile factor which interferes with fat absorbtion by causing a deficiency in bile salt production according to the evidence of Garlich and Nesheim (1965), who restored raw soybean-depressed fat absorbtion by dietary supplements of sodium taurocholate in the young chick. The data are consistent with a vagally-induced stimulation of the reflexing or anti-peristaltic action of the duodenum, together with enhanced pancreatic and biliary secretions, provoked by a heat labile factor in raw soybean. The exact mechanism by which the factor interferes with the absorbtion is not known. It is possible that the products of lipolysis become bound to the undigested protein shown to be present in the jejenum of the chick fed raw soybean (Bielorai et al. 1973) and are thus rendered unavailable for micelle

formation, in a manner not unlike that shown for free cholic acid (Serafin and Nesheim 1970) under similar dietary conditions. In the present study, ALD tended to be somewhat lower for chicks as opposed to adults (69.1 vs 79.5%). In addition, birds in both age groups benefited from heat treatment in terms of improved ALD indicating that there may be a heat-labile factor in raw CS that operates in a manner not unlike that proposed for raw soybeans and this may account for the depressed AMEn values observed when chicks are fed raw CS.

The use of dysprosium chloride ($DyCl_3.6H_20$) as an inert marker is beginning to find wide acceptance in ruminant and porcine studies, but little work has been done examining its application in avian species. The most common marker in poultry digestibility studies has been chromic oxide (Cr_2O_3). Cr_2O_3 has been found to yield more precise but not necessarily more accurate data, when compared to the total collection technique (Sibbald 1982). Coates et al. (1977) found that the Cr_2O_3 procedure gave lower but less variable AME values than did the total collection procedure. The attraction of indicators lies in their ability to permit the derivation of acceptable BE values even when feed is spilled and some excreta are not recovered. As the marker is not absorbed by the bird its concentration in digesta will gradually increase as it passes through the digestive tract. Thus the higher the digestibility of the feed, the greater will be the concentration of marker in the feces. This close relationship between marker concentration and digestibility can thus be used to estimate BE. $DyCl_3.6H_20$ was selected in this study because of its applicability (high nuclear cross section for thermal neutrons, 2700 barns, and short half life which permits rapid buildup of the radioisotope) to the instrumental neutron activation analysis (INAA) available at the University of Alberta SLOWPOKE facility.

Kennelly et al. (1980), examining the potential of $DyCl_3.6H_20$ as an inert marker for pigs, used an infusion concentration of 25.4ppm elemental Dy and obtained dry matter digestibility coefficients (%) close to that obtained for total collection grab samples. They found that dry matter digestibilities (DMD) were similar irrespective of the day of sampling. This absence of significant daily variation suggested to them that DMD could reliably be

determined by taking subsamples from daily composite samples on any day following a 7-day adaptation period. They found that higher digestion coefficients were consistently obtained from morning sampling which could be associated with a longer digesta retention time in the animal. The quantitative recovery (100.00±2%) of ingested dysprosium in fecal samples from that study is in close agreement with Ellis (1968) who concluded that Dy is essentially unabsorbed from the intestinal tract of ruminants.

In the present study, an infusion concentration of 15ppm elemental Dy was used in view of the small body size of chickens and the relatively low feed spillage obtained in previous ME trials. The $DyCl_3.6H_20$ was incorporated into diets intended for a standard apparent metabolizable energy (AMEn) assay using the total collection technique. The recovery rates obtained (Table IV.4) were generally quite high and in this respect are similar to those obtained by Kennelly et al. (1980). There were consistently higher recovery rates (with lower standard errors) for young birds as opposed to those from adult birds. This trend seems to be a reflection of the duration of the post-collection fast period (16 hrs for chicks vs 24 hrs for adults) and the relative growth rates of the former age group. The four-week old chicks grow and actively assimlate ingested feed at a faster rate than would be expected with adult birds. This phenomenon would tend to reflect itself in faster overall rates of passage of digesta through the gut. A 16 hr post-collection fast period would thus appear to be adequate to induce total gut clearance and thus ensure almost complete quantitative recovery of the inert digestive marker in chicks.

In the case of adult cockerels, recovery rates were somewhat lower than with chicks, with much higher variation (±3.6 vs ±1.4%) than that found with chicks. Individual recovery rates ranged from 55.9% to 100.0%. This much larger variation (and lower resultant recovery rates), may be due to two factors. Adult cockerels are assumed to be growing at a much reduced rate compared to the growth rate of chicks because they are expected to be at that region of the growth curve where growth rate approaches a constant. In addition, adult birds tend to start feeding as soon as the barn lights are switched on (about 1 hr prior to post-collection feed removal). The possibility would thus exist that birds are able to fill their

crops before feed removal. This, coupled with a post-collection fast time of only 24 hrs may account for some of the variability in recovery rates. Assuming that the post-collection period is insufficient to induce total gut clearance in adult cockerels with full crops, then lower recovery rates should be evident for diets that are highly palatable (corn-soybean meal controls). This was indeed the case in one instance (55.9% recovery rate). It would appear that the post-collection starvation period should be increased in feeding trials in which Dy is to be used as a digestibility marker for adult cockerels. Alternatively, the birds could be fed Dy-free diets, (of the same composition as the test diets) for an additional 24-36 hrs and grab samples samples taken intermittently to determine the maximum post-collection time required to ensure quantitative recovery of Dy in adult cockerels (B. V. Turner, pers. comm.).

Comparison of the AMEn estimates generated using the total collection method (Table IV.2) and the Dy-collection technique (Table IV.3) showed that the estimates for the AMEn of jet-sploded CS are in much closer agreement than those obtained for raw CS. The reason for this discrepancy is not apparent, but it may be related to the presence of a heat-labile factor present in raw CS alluded to earlier. One would expect that the chick values obtained by both methods would be in closer agreement in view of the high Dy-recovery rates (Table IV.4). The same GE, Kjeldahl-N and DM values were used in both calculations, so one would expect that any introduced experimental error would not be manifested in the final AMEn estimates. However, one should be cautioned when interpreting these results and dismissing one technique in favor of another. Because of dietary constraints, such as problems with unpalatability, CS cannot be incorporated into chicken diets much above 20% inclusion without affecting voluntary feed intake. Since the regression equation is generated using five AMEn estimates (0, 5, 10, 15, and 20% CS), any standard regression estimate error can only be applied to that section of the regression line between these five data points. Extrapolation of the line to 100% CS inclusion gives an estimate of the AMEn but would of necessity magnify apparent errors some five times. Hence these AMEn estimates are just that and cannot be compared directly. The appropriateness of a given set of AMEn values must thus be

judged on other parameters to determine what analytical method or technique produces more consistent results between trials and ultimately between laboratories.

Nonetheless, the Dy-marker technique does hold several advantages over the total collection technique currently being used to determine AMEn. This method would, in its purest form, be less labour intensive than that of the latter as it does not require the quantitative recovery of feces during the collection period. Grab samples may be used to estimate GE, Kjeldahl-N and DM of feed and feces. It also negates the need to accurately weigh out feed and feces recovered and monitor feed DM during the trial, as is required with the total collection procedure. This would thus mitigate errors due to unrecovered feed or feces. However, further experimentation seems warranted regarding the merits of post-collection fasting in a Dy-marker assay. It is probable that Dy-flux in the bird is affected by the pre-collection fast as well, which is an essential step in the total collection method used as a vehicle for Dy-infusion in the present trial. It may well be that the use of Dy as a digestive marker in birds necessitates a different experimental design to ensure quantitative recovery and prevent disruption of the Dy-flux in the body once peak Dy-levels have been reached.

E. SUMMARY

The experiments reported herein were conceived with two main objectives in mind: to provide estimates of the TMEn and AMEn of raw full-fat Tobin CS and optimally jet-sploded full-fat CS and to compare AMEn estimates derived from the total collection and dysprosium ratio techniques using the standard AMEn collection procedure. TMEn values for the raw CS and optimally jet-sploded CS were not significantly different (5.04 vs 5.05 kcal/gDM, respectively)($t = -0.09$ with 14 df). Thus, based on these results, jet-sploding does not appear to benefit poultry in terms of improved TMEn. However, when voluntary feed intake is taken into account and BE is estimated using the standard AMEn procedure, both adults and chicks demonstrated improved ME's from the jet-sploded product (5.06 vs 4.26 kcal/gDM) and (4.39 vs 3.80 kcal/gDM), respectively. Lipid digestibilities in both adults and

chicks were significantly ($P<0.001$) improved by jet-sploding with adults demonstrating significantly higher ($P<0.001$) apparent lipid digestibilities than did chicks. This finding may in part explain the lower AMEn results obtained from chicks compared to those derived from adult birds.

The high $DyCl_3.6H_2O$ recoveries approaching quantitative recovery bodes well for continued experimentation on its use as an inert digestibility marker for avian species and lends credence to the AMEn estimates derived using this technique. However, the results of this trial, because of their preliminary nature should not be used to categorically dismiss the results of one analytical technique in favour of the other.

Table IV.1. Composition of basal diet and mineral and vitamin supplements for the basal and test diets.

Ingredient	(g)
Basal diet	
Ground corn	60.00
Soybean meal (47% protein)	38.75
Corn oil, refined[1]	1.00
DL-Methionine	.25
Supplement	
Biophos	1.80
Limestone flour	1.35
Salt, iodized (.007% I)	0.25
Vitamin mix[2]	0.20
Mineral mix[3]	0.10

[1]Mazola, Canada Starch Co. Ltd., Toronto, Ontario.
[2]Vitamin mix provided per kg of diet: 12,000 IU vitamin A; 1,000 ICU vitamin D_3; 10 IU vitamin E; 2 mg menadione; 5 mg riboflavin; 10 mg d-calcium pantothenate; 25 mg niacin; 750 mg choline chloride; 1 mg folic acid; 10 μg vitamin B_{12}; 3 mg pyridoxine hydrochloride; 200 μg d-biotin; 2 mg thiamin hydrochloride; 125 mg ethoxyquin.
[3]Mineral mix provided per kg of diet: 60 mg manganese ($MnSO_4.4H_2O$); 50 mg zinc (ZnO); 0.40 mg iodine (KIO_3); 0.1 mg Selenium (NA_2SeO_3); 5 mg copper ($CuSO_4.5H_2O$); 30 mg iron ($FeSO_4.7H_2O$).

Table IV.2. Effect of Jet-sploding on the apparent metabolizable energy (AMEn) values of canola seed as determined by the total collection technique.

Jet Sploding Temperature	n	r^2	a	b	Sy.X	AMEn
(°C)				(Kcal/gDM)		
116						
Chicks	5	0.882	3.156	1.232	0.041	4.39
Adults	5	0.951	3.344	1.717	0.036	5.06
Untreated CS						
Chicks	5	0.900	3.127	0.668	0.020	3.80
Adults	5	0.843	3.354	0.901	0.036	4.26

n, levels of inclusion of canola seed; r^2, coefficient of determination; Sy.X, standard error of estimate; AMEn, apparent metabolizable energy content of a test ingredient corrected to nitrogen equilibrium and predicted by substitution in the regression equation, $Y = a + bX$, when $X = 1$.

Table IV.3. Effect of Jet-sploding on the apparent metabolizable energy (AMEn) values of canola seed as determined by the dysprosium chloride marker technique.

Jet Sploding Temperature	n	r^2	a	b	Sy.X	AMEn
(°C)				(Kcal/gDM)		
116						
Chicks	5	0.963	3.210	1.301	0.024	4.51
Adults	5	0.959	3.308	1.645	0.031	4.95
Untreated CS						
Chicks	5	0.065	3.144	0.220	0.076	3.36
Adults	5	0.059	3.293	0.179	0.066	3.47

n, levels of canola seed; r^2, coefficient of determination; Sy.X, standard error of estimate; AMEn, apparent metabolizable energy content of a test ingredient corrected to nitrogen equilibrium and predicted by substitution in the regression equation, $Y = a + bX$, when $X = 1$.

Table IV.4. Percent recovery of elemental dysprosium (Dy) from young and adult chickens.

Jet-Sploding Temperature	Dietary level of canola seed	Chick Dy recovery	Adult Dy recovery
(°C)	(%)	(%)	(%)
Control diet	0	96.2a	79.1a
Untreated CS	5	92.7ab	84.9a
	10	88.6bc	88.5a
	15	87.3c	78.1a
	20	95.6a	88.9a
116	5	96.0a	88.5a
	10	95.5a	88.8a
	15	98.9a	93.0a
	20	98.3a	88.7a
SEM[1]		1.4	3.6

[1]SEM, standard error of treatment mean of four replicates.
a,b,c Column values with the same letter are not significantly different as determined by the Student-Newman-Keuls test ($P<0.05$).

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V. Conclusions

Experiments were conducted to study the effects of supplemental full-fat canola seed (CS) (*Brassica campestris* cv Tobin) on the performance of laying hens and broiler chickens. The feasibility of using Jet-Sploding^{TM} to improve the nutitive value of raw CS for broilers and of using dysprosium chloride ($DyCl_3.6H_2O$) as an inert marker in poultry digestibility studies were also examined.

In the first experiment, studies were carried out to determine the effects of supplementing diets containing barley, wheat and ground corn as the sole cereal ingredient with zero and 10% whole CS on the biological and economical performance of laying hens. Egg production expressed in terms of percent hen-day or percent hen-housed production and average numbers of eggs produced on a hen-housed or hen-day basis was not significantly ($P>0.05$) affected by dietary treatment. Feed intakes and feed efficiency were significantly lower for laying hens fed both corn and canola supplemented diets. Of the cereal grains used, birds fed the corn-based diets tended to produce the largest eggs. Despite the poorer biological performance, barley-based diets cost significantly ($P<0.05$) less than either wheat or corn-based diets. Thus net income was largest for birds fed barley-based diets. Income was not significantly ($P>0.05$) affected by the addition of CS to the diet. Thus, based on the results obtained in this study, it would appear that CS can be used at a level of 10% as a satisfactory energy supplement in barley and wheat-based rations for laying hens without affecting economic returns.

In the second experiment, studies were conducted to estimate the true metabolizable energy (TMEn) values of raw, ground and jet-sploded whole CS, and to determine the nutritive value of these feeds for broiler chickens. The mean TMEn values ($\pm$ SE) were 5.14 ± 0.08 and 5.15 ± 0.08 kcal/gDM for the raw and jet-sploded samples, respectively. Jet-sploding resulted in slightly high ether extract values in the samples and in the complete elimination of myrosinase activity. There was,however, no significant ($P>0.05$) improvement in the TMEn values of jet-sploded CS as compared to those from the raw seed. In a trial with broiler chickens weight gains to 3 weeks of age were not increased by jet-sploding, althqugh

feed:gain values were significantly ($P<0.05$) improved, and were equivalent to those obtained from the corn-soybean meal controls. Based on these results, it is suggested that a temperature of 116°C in the Jet-Sploder (for 22.2 sec) results in effective elimination of myrosinase and maximal oil liberation.

In the third experiment, studies were undertaken to estimate the true (TMEn) and apparent metabolizable energy (AMEn) values of raw, ground and optimally heated (116°C) jet-sploded whole CS. An investigation was conducted concurrently to examine the feasibility of using dysprosium chloride ($DyCl_3.6H_2O$) as an inert marker in poultry digestibility studies. TMEn values for the raw, and jet-sploded (116°C) CS were not significantly different (5.04 and 5.05 kcal/gDM)($t=-0.09$ with 14 df). However, when voluntary feed intake was taken into account and bioavailable energy (BE) estimated using the standard AMEn procedure for both adults and chicks demonstrated improved ME's from the jet-sploded product (5.06 vs 4.26 kcal/gDM) and (4.39 vs 3.80 kcal/gDM), respectively. Lipid digestibilities in both adults and chicks were significantly ($P<0.001$) improved by jet-sploding with adults demonstrating significantly higher ($P<0.001$) apparent lipid digestibilities. This may in part explain the lower AMEn results obtained from chicks compared to those derived from adult birds.

Dysprosium chloride ($DyCl_3.6H_2O$) was included in the AMEn diets at 15ppm and the induced radioactivity in feed and fecal samples, following irradiation in the Canadian SLOWPOKE reactor, was measured with a Ge(Li) detector coupled to a 4096 multichannel analyser. AMEn estimates using the dysprosium (Dy) ratio technique for raw CS were 3.47 and 3.36 kcal/gDM for adults and chicks respectively. AMEn estimates for the jet-sploded product were 4.95 and 4.51 kcal/gDM for adults and chicks, respectively. Mean Dy recovery in chicks following a 16 hr post-collection fast was $94.3\pm1.4\%$. Mean Dy recovery in adults following a 24 hr post-collection fast was $86.5\pm3.6\%$. These relatively high recoveries indicate that Dy is a very good inert marker for digestibility studies in avian species and lends credence to the AMEn estimates derived using this technique.